IMPACT OF NEW TECHNOLOGY AND SOURCING PRACTICES
IN
MANAGING MANUFACTURING FLEXIBILITIES

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CERTIFICATE

Certified that the thesis entitled, '**IMPACT OF NEW TECHNOLOGY AND SOURCING PRACTICES IN MANAGING MANUFACTURING FLEXIBILITIES'**, being submitted by Jaspreet Singh Oberoi, to Department of Mechanical Engineering, Thapar University, Patiala, in fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY**, is a record of bonafide research work carried out by him under our guidance and supervision. The matter presented in this thesis has not been submitted in part or full to any other University or Institute for the award of any degree.

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CONTENTS

ABSTRACT

Fast and dramatic changes in customer expectations, competition, and technology are creating an increasingly uncertain environment. To respond, manufacturers are seeking to enhance flexibility across the manufacturing system. Manufacturing flexibility has been heralded as a major competitive tool for manufacturing organizations to provide 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 and can be achieved through a variety of techniques and methods. The study has been conducted with an objective to assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

The research has been carried out using flexible system methodology. The problem has been conceptualized as an S-A-P (Situation-Actor-Process) paradigm. In this framework, the 'situation' aspect comprises of the present industrial situation in the manufacturing sector, whereas the organization constitutes the 'actor' aspects. The role of new technology vis-à-vis sourcing practices in managing manufacturing flexibility constitutes the 'process'. The literature on the nature, types and levels of manufacturing flexibility has been explored in detail. This has essentially focused on the management of the new technology and sourcing practices as a way to achieve the manufacturing flexibilities at various levels. A simple, relevant and comprehensive questionnaire pertaining to the desired conceptual framework has been peculiarly designed, which seeks information on the status of different dimensions of manufacturing flexibility and various methods for achieving it in the Indian manufacturing industry. Special emphasis has been given to seek information related to business strategy and performance of the organizations, status of volume, modification, delivery and manufacturing flexibility and the role of technology and sourcing practices in achieving different flexibilities. The questionnaire has been designed after extensive literature review and validated through peer review from academicians, consultants and practitioners from the industry. A 1–5 Likert-type scale has been employed for all item measures in the questionnaire. Descriptive and empirical analyses of the data collected through the survey has been carried out to assess the status of new technology vis-à-vis sourcing practices and present level of manufacturing flexibility at tactical and strategic level. Further, the associations between

various independent constructs and different manufacturing flexibility dimensions have been established using canonical correlation and multiple regression analysis.

The survey has been followed by critical assessment of four case studies in the surveyed manufacturing organizations. The objective of the case studies has been to look into and critically analyze various facets of working of the organizations concerning the research objective. Accordingly, the case studies have been conducted at Maruti Suzuki India Limited (MSIL), Gurgaon; Sona Koyo Steering Systems Limited (SKSSL), Gurgaon; Moserbaer India Limited (Mosebaer), Noida; and Punjab Tractors Limited (PTL), Mohali. Various factors related to new technology and sourcing practices as mentioned earlier have been studied through case studies. Only those factors, which were reflected as the potential factors have been taken up for detailed study. In each case study, the various aspects concerning purpose of study that include; organization business strategy and initiatives, performance indicators, manufacturing capacity and capabilities, role of technology and sourcing practices, status of manufacturing flexibility, relative performance of technology and sourcing practices and social and environment aspects have been analyzed for achieving manufacturing flexibilities. The analyzed result of the case studies depicts the total industrial scenario about the achieved level of manufacturing flexibilities and assesses the relative impact of sourcing practices and new technology on different flexibilities.

The learning issues of survey and case studies have been synthesized to bring out a systematic implementation plan for effectively managing the different flexibilities in manufacturing organizations. For this, a qualitative modeling technique has been applied using options field methodology (OFM), options profile methodology (OPM), analytic hierarchy process (AHP) and fuzzy set theory (FST). Various profiles for course of actions planned for new technology and sourcing practices have been developed and includes; manufacturing technology based approach, design technology based approach, infrastructural technology based approach, outsourcing based approach and strategic sourcing based approach. The order of implementing various strategies for successfully achieving the different manufacturing flexibilities at tactical and strategic level in Indian context has been highlighted.

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NOMENCLATURE

AHP	Analytic Hierarchy Process
AMHS	Automated Material Handling Systems
AMT	Advanced Manufacturing Technology
AS/RS	Automated Storage And Retrieval System
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CNC's	Computer Numerical Control Machines
DF	Delivery Flexibility
EBITDA	Earnings before Interest, Taxes, Depreciation and Amortization
ERP	Enterprise Resource Planning Systems
FMS	Flexible Manufacturing System
FST	Fuzzy Set Theory
GT	Group Technology
IT	Information Technology
MANF	Manufacturing Flexibility
MF	Modification Flexibility
Moserbaer	Moserbaer India Limited
MRP	Material Requirement Planning
MRP II	Manufacturing Resource Planning
MSIL	Maruti Suzuki India Limited
OA	Office Automation
OEM	Original Equipment Manufacturer
OFM	Option Field Methodology
OPM	Option Profile Methodology
OS	Outsourcing Based Approach
PAT	Profit after Tax
PTL	Punjab Tractors Limited
PV	Photovoltaic

R & D	Research and Development
RO	Robotics
ROCE	Return on Capital Employed
RP	Rapid Prototyping
SAP	Situation-Actor-Process
SAP-LAP	Situation - Actor - Process – Learnings - Action - Performance
SCM	Supply Chain Management
SCOMP	Supplier Competencies
SIDCR	Supplier involvement in Delivery Changes Request
SIMP	Supplier involvement in Modifying Products
SIVCR	Supplier involvement in Volume Changes Request
SKSSL	Sona Koyo Steering Systems Limited
SREL	Supplier Relationship
SS	Strategic Sourcing based Approach
SWOT	Strength, Weaknesses, Opportunity, Threat
T_D	Design Technology based Approach
TDE	Technology investment in Manufacturing Design
T_I	Infrastructural Technology based Approach
TIMS	Technology investment in Manufacturing Infrastructure
T_M	Manufacturing Technology based Approach
TMSYS	Technology investment in Manufacturing Systems
VA	Value Analysis
VE	Value Engineering
VF	Volume Flexibility

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CHAPTER I
INTRODUCTION

1.1 Present Scenario

Expanding global competition, rapidly changing markets and technology, increasing complexity and uncertainty are creating a new competitive environment. Organizations 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, competitiveness and profitability call for improved organizational adaptability and more flexible and advanced systems (relative to manufacturing, engineering, supply chain, information and process technology, etc.) to improve manufacturing competence. The manufacturing organizations have also experienced an unprecedented degree of change in the recent times, involving drastic changes in management approaches, product and process technologies, customer expectations, supplier attitudes as well as competitive behavior.

The basic competitive priorities generally considered by academician and professionals are quality, delivery, price and flexibility. However, the past decade has witnessed an increased interest in flexibility, which bestows on a firm the ability to respond promptly to market opportunities and changing technologies and most likely to continue with ever increasing changes in the marketplace. The investigation of 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, indicates the need of matching the manufacturing flexibility with environmental uncertainty to ensure profit and sales performance (Chang *et al.*, 2002).

Manufacturing flexibility has been heralded as a major competitive weapon for manufacturing organizations operating in increasingly uncertain environments and turbulent markets. It has been considered in the literature 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.

Past research on manufacturing flexibilities has mainly tended to focus on newer technologies as a means for achieving manufacturing flexibility goals. Various researchers have concluded that there is a positive relationship between newer technologies and flexibility (Singh *et al.*, 1996; Dangayach and Deshmukh, 2005; Narasimhan *et al.*, 2004). It has also been found and presented by many researchers that manufacturing technology represents just one method of delivering flexibility (Jaikumar, 1986; Gerwin, 1993; Upton, 1995; Das, 2001). Researchers have begun to look beyond advanced manufacturing systems to alternative methods 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 programmes (McCutcheon *et al.*, 1994). However, there has been a growing recognition of the contribution of sourcing practices to the attainment of competitive excellence and better potential to influence an organizations' flexibility in responding to market demands. The system has witnessed a transformation in which suppliers and customers are inextricably linked throughout the entire sequence of supply chain. Considerable anecdotal evidence exists to suggest the use of sourcing practices as an alternative strategy for obtaining manufacturing flexibilities (Tully, 1994). Some studies have found positive relationships between sourcing and different kind of manufacturing flexibilities (Olhager, 1993; Suarez *et al*., 1996; Narasimhan and Das, 2000; and Gupta, 2005), but are incomplete in their examination of the different dimensions and specific of such relationships. Moreover, there is also lack of any organized attempt to understand how these activities are being carried out in Indian manufacturing industry.

This research is intended to understand the complexities involved in managing manufacturing flexibility at firm level, and their linkages with technology and sourcing practices in manufacturing industry. The purpose of this work is to understand and explicate the interaction between new technology, sourcing practices and manufacturing flexibilities and assess their relative impact on different flexibilities.

1.2 Concept of Flexibility

The concept 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). 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). 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. 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 that an organization may employ 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 that there are usually multiple responses to the same set of problems. Sushil (1997) advocates the concept of systemic flexibility, which is defined as the exercise of free will or freedom of choice on the continuum to synthesize the dynamic interplay of thesis and antithesis in an interactive manner, capturing the ambiguity in the systems, and expanding the continuum with minimum time and effort. Sushil (2000) identified strategic, organizational, financial, information systems and manufacturing flexibility as the cornerstones of enterprise flexibility. Zhang *et al.* (2006) perceives flexibility as the organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses. Boppana *et al.* (2007) captured the complexities from the flexibilities and fit them into entity-relationship model and also gives an idea of how the developed individual models can be used to evaluate the flexibility options in a manufacturing system.

1.3 Manufacturing Flexibility

Manufacturing flexibility, the focus of the study, 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 or performance. (Gerwin, 1993; D'Souza and Williams, 2000; Koste and Malhotra, 1999; Barad and Sipper, 1988). 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 considered as the strategic element of business, along with price (cost), quality, and dependability. Priorities assigned to each of these factors determine how an organization positions itself relative to its competitors.

A great deal of research in defining various types of flexibilities in manufacturing has occurred over the last two decades. Despite this, there is no general agreement on how to define flexibility. At the outset, this is due to the multidimensional nature of flexibility and the various views of flexibility that result: flexibility has been viewed and studied as a physical property, an attribute of decision making, an economic indicator, and a strategic tool. Understanding the constituent dimensions of manufacturing flexibility and their interrelationships would be of value to the firms whose competitive strength depends on flexible manufacturing. Its dimensions addressed in the literature mainly include equipment flexibility, material flexibility, routing flexibility, material handling flexibility, program flexibility, mix flexibility, volume flexibility, modification flexibility, new product flexibility, delivery flexibility and market flexibility.

The development of a generic categorization is likely to remain elusive in the previous research as manufacturing flexibility manifest itself in many forms at various levels in an organization. Yilmaz and Davis (1987) have examined manufacturing flexibility through different dimensions of time. 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 including sequencing and scheduling. While tactical flexibilities relate to the embodiment in technological and organizational routines of responses in how to deal with changes in rates of production, product mix over the course of a business cycle, strategic flexibilities are external in application and relates to how the organization is positioning itself with respect to future challenges and opportunities. D'Souza and Williams (2000) categorized manufacturing flexibility as external and internal driven dimensions. This study focuses on the generalization of hierarchical taxonomy of manufacturing flexibilities based on the insights of the available literature.

Volume flexibility, in context to this study, corresponds to the ability of manufacturing system to be operated profitable (in the short term) with various amount of volume for several products without incurring negative effects (e.g. time delays, changes in performance outcomes) when switching from one operation to another (Sethi and Sethi, 1990, Koste and Malhotra, 1999, Hyun and Ahn, 1992). However, the issues related to ease of producing minor alterations in product design to meet customization or differentiation requests have been addressed by modification flexibility (Gerwin, 1993). Modification flexibility is useful for product and market differentiation efforts and overall market share growth. Delivery flexibility further strengthens the capabilities of manufacturing system to respond to or influence market changes & enables the rapid delivery of innovativeness, customized products for new market creation (Narasimhan and Das, 2000).

1.4 Technology

The word 'technology' comes from two Greek words *'Techne'* and *'Logos'*. *'Techne'* means the skill or craft needed to make something and *'Logos'* mean discussion or knowledge of something (Rao, 1996). Technology is defined as the practical knowledge, know-how, skill and artifacts that can be used to develop a new product or service and/or a new production/delivery system (Moriarity *et al.*, 1990). 'Technology refers to a system of components which act on or change an object from one state to another'. The components include hardware, software and programs to transform materials or information from one state to another (Goodman and Griffith, 1991). Technology is purposeful application of knowledge developed in various areas that include hardware or software; general or firm specific; and alternative, intermediate or appropriate.

1.4.1 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. In the field of manufacturing generally termed as advanced manufacturing technology (AMT), application of new technologies can result in reduction the cost, improvement in quality and flexibility, more responsiveness to market demands and introduction of new products more rapidly, at the same time (Hayes, 1991).

1.4.2 Advanced Manufacturing Technology

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). 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.

The overall potential of AMT is immense and several problem issues in design, manufacturing or administrative activities could be solved through increased use of it. Improvements in product quality, manufacturing flexibility, increased profitability, and improvements in productivity due to a reduction in the rejection rates are the most often-cited benefits from technology adoption. 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. Flexible manufacturing systems (FMS), use of robots and automated materials handling systems reduce set-up times and other interruptions so that products flow more smoothly and faster through the plant. Integrated production control systems, such as manufacturing resource planning (MRP II) and enterprise resource planning systems (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.

Koh *et al.* (2005) examines how and to what extent uncertainty affects small and medium scale enterprise 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 AMTs 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.

1.5 Sourcing Practices

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. Sourcing is seen somewhat narrowly as finding sources of supply, guaranteeing continuity in supply, and ensuring alternative sources of supply and gathering knowledge of procurable resources. A rather broader definition of sourcing views it as “the entire set of business processes required to purchase goods and services including the selection of suppliers, design of supplier contracts, product design collaboration, procurement of material and evaluation of supplier performance" (Chopra and Meindl, 2003).

Oberoi and Khamba (2005a) aim to develop the buyer- supplier typology for strategic archetypes of sourcing 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 strategy. The four sourcing strategies are classified in light of research literature as: make-or-buy, outsourcing, insourcing and strategic sourcing.

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). 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). Narasimhan (1999) describe strategic sourcing as a way to obtain manufacturing capabilities without capital investments and defines strategic sourcing as the use of supplier competencies to achieve flexibility goals through: a strategic alliance with suppliers; and formal incorporation of supplier capabilities into a firm's manufacturing strategies. 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'.

Preceding studies have found varied relationships between sourcing and different manufacturing flexibilities (Suarez *et al.* 1996, Narasimhan and Das, 2000 and 2004). 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. Gupta *et al.* (1998) studied the impact of competitive priorities, process innovations and time-based competition in the manufacturing sector of industrializing economies on the cost, quality, flexibility and time and found manufacturing industry at an earlier, quality-dependent. 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. Bhardwaj *et al.* (2006) focuses on the partnership between Indian automotive vendors and vehicle manufacturers for product design activity and found a lot of variation with respect to this activity for different clusters.

From the view point of various researchers, 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.

1.6 Flexible Systems Methodology

Flexibility can be defined as the ability to respond effectively to the ever changing and increasing needs of the customer. For this demand to be satisfied, flexibility should be built into the total chain of acquisition, processing, and distribution stages. As a result, there is an increasing interest in flexibility and flexibility enabling mechanisms/ parameters to achieve the best strategy for obtaining the right and desired. High speed and accuracy combined with flexibility and optimized throughput, are the goals of the next generation of machines.

The philosophy of integration of quantitative and qualitative tools is emerging very rapidly to cater to the need of diverse decision-making and managerial processes. There are number of end of the continuum paradoxes which have created separate schools of thought. A concept of flexibility can provide a solution to the paradox and advocates that it is not necessary to invent a new approach to each problem situation or to settle at an end of continuum.

In essence, flexible systems methodology states that for a problem situation an approach out of the existing well researched once or a suitable combination or innovation of them should be selected and integrated to match requirements of the problem situation. It thus integrates all the systems approaches and techniques into a family in which everyone either individually or collectively contributes meaningfully. Flexible system methodology is built on spectral and integrative paradigm. Sushil (1994) discusses this paradigm and concludes that this methodology is more realistic and by using this, more creativity will be applied to the problem solving.

It is planned in this research to use flexible system methodology for exploring and explicating the nature of interactions between manufacturing flexibility, new technology and sourcing practices in manufacturing industry.

1.7 Objective and Research Issues

1.7.1 Objective of the Study

The objective of this research work is to assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

1.7.2 Issues Covered

Following issues have been taken up during the research work.

i. To recognize manufacturing flexibilities as multi-dimensional and multilevel concept and define manufacturing flexibilities in this context.
ii. To understand and explicate the nature of interaction between new technology, sourcing practices and manufacturing flexibilities.
iii. To assess the impact of new technology vis-à-vis sourcing practices on manufacturing flexibilities.
iv. To explore and examine the relative impact of sourcing practices and new technology at different levels of manufacturing flexibilities.
v. Examine the implications of sourcing-flexibility and new technology-flexibility relationship.
vi. Consideration of related technical, social and environmental issues while achieving the manufacturing flexibilities.
vii. Establishing relationship between variables and parameters associated with manufacturing flexibilities.

1.8 Scope of the Work

The work shall be limited to those medium and large scale manufacturing enterprises of the region, which are in the process of achieving the manufacturing flexibilities at all or various levels by acquiring, developing or utilizing the advanced manufacturing technology or by the use of specific/different sourcing practices with different aspects of manufacturing flexibilities.

It is proposed to focus on three dimensions of manufacturing flexibility - volume flexibility, modification flexibility and delivery flexibility as sourcing will mostly influence these dimensions. 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 flexibility appear at the plant or organization level. Suppliers mainly interface with their customers at the plant or organization level. Hence, it is more likely that sourcing will influence these dimensions of manufacturing flexibility. In addition, 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, delivery and new product flexibility (Olhager, 1993; Suarez *et al.*, 1996; Narasimhan, 2004).

1.9 Overall Methodology

The research has been carried out to assess the impact of new technology and sourcing practices in managing manufacturing flexibilities, using flexible system methodology. The literature on the nature, types and levels of manufacturing flexibility has been explored in detail. A methodical review on the concept, taxonomy and related facets of technology and sourcing practices, as a method to achieve the manufacturing flexibilities, has also been done. The literature has also been reviewed on the methodologies to be used in carrying out the research. The problem has been conceptualized as an S-A-P (Situation-Actor-Process) paradigm.

The survey has been conducted in the manufacturing organizations that are in the process of achieving the manufacturing flexibility at all or various levels by acquiring, developing or utilizing the advanced manufacturing technology or by the use of specific/different sourcing practices. Descriptive and empirical analyses of the data collected through the survey has been carried out to assess the status of new technology vis-à-vis sourcing practices and present level of manufacturing flexibility at tactical and strategic level. In data analysis, independent and dependent variables (constructs) have been formulated based on literature review and the objectives of this research. The convergent and discriminant validity of the constructs and their measures have been done and various statistical tools and techniques have been employed using SPSS software to predict the results. Since the research was focused on investigating the relationships between a set of multiple dependent and multiple independent variables with little prior knowledge of such relationships, canonical correlation analysis was deemed the appropriate multivariate statistical technique to use. As a precursor to canonical correlation analysis, the pair-wise correlations between variables were examined and variables were selected to avoid problems of multicollinearity. For a closer examination of relationships between individual dimensions of dependent variables with the independent variables, the multiple regression analyses have been done using the enter and stepwise method.

The survey has been followed by critical assessment of four case studies in the surveyed manufacturing organizations. The objective of the case studies has been to look into and analyze various facets of working of the organizations concerning the research objective. The analyzed result of the case studies depicts the total industrial scenario in manufacturing sector about the achieved level of manufacturing flexibilities and assesses the relative impact of sourcing practices and new technology on different flexibilities for providing a basis for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities. S-A-P analysis has been done in each case study and their learning issues have also been listed.

The learning issues of survey and case studies have been synthesized to bring out an implementation plan. For this, qualitative modeling techniques have been applied. Finally, the critical learning issues of the survey and case studies have been synthesized. In view of the insights gained from this synthesis and the literature available, the actions for implementation in the manufacturing sector have been recommended.

1.10 Organization of the Thesis

The write up of the thesis is divided into seven chapters: I. Introduction, II. Literature Review, III. Design of Study, IV. Survey Based Research Results, V. Case Studies, VI. Development of an Implementation Plan for Managing Manufacturing Flexibilities, and VII. Conclusions and Recommendations.

Chapter I highlights the need for managing manufacturing flexibility, and its association with technology and sourcing practices in the manufacturing industry. Further, the objectives and issues, scope of study, overall methodology and organization of research work has been covered in this chapter.

Chapter II reviews in detail the previous studies on the concept of flexibility, and nature, types and levels of manufacturing flexibility, advanced manufacturing technology, sourcing practices and their relationships. Special emphasis has been laid on the impact of new technology and sourcing practices as a way to achieve manufacturing flexibilities at various levels. The literature has also been reviewed on methodologies to be used in carrying out the research.

Chapter III introduces overall design of study, which includes phases of research and the methodology adopted for carrying out the research work. The details of work done in each phase, tools, techniques and models used in the dissertation have also been presented in this chapter. Flexible system methodology, used for the purpose has been explained. Methodology of conducting empirical study (survey) and case studies has been explored. Use of qualitative modeling to develop a management process, and an implementation plan has also been discussed.

Chapter IV presents the results of detailed survey conducted in various manufacturing enterprises. A survey of various manufacturing organizations, involved in achieving manufacturing flexibilities at tactical and strategic level has been taken up by using a peculiarly designed questionnaire. Descriptive and empirical analyses of the data, collected through the survey, has been carried out to assess the status of present level of different dimensions of manufacturing flexibilities and impact of new technology and sourcing practices in managing it.

Chapter V describes the detailed case studies carried out in four manufacturing organizations. In each case study, the methods/techniques/approaches adopted for achieving manufacturing flexibilities, the success achieved, the modifications made in the future plans have been compiled and analyzed in detail. The case studies have been conducted in Maruti Suzuki India Limited (MSIL), Gurgaon; Sona Koyo Steering Systems Limited (SKSSL), Gurgaon; Moserbaer India Limited (Moserbaer), Noida; and Punjab Tractors Limited (PTL), Mohali. The preliminary information provided by the survey has been validated by these case studies and the synthesis of the two has provided the required results.

Chapter VI synthesizes the learning issues from survey and case studies and utilizes the same in the domain of qualitative model to select appropriate strategies and develop suitable plan for managing manufacturing flexibilities. The qualitative modeling involves the use of Options Field Methodology (OFM), Options Profile Methodology (OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST). The learning issues of questionnaire survey and case studies have been converted to various options using OPM.

Various profiles or courses of actions, to achieve manufacturing flexibility have been decided based upon implementation of new technology and sourcing practices. Various objectives of the organizations as revealed by the survey were utilized in the qualitative model. The weightings of these objectives have been worked out by experts using AHP. Further, the expert opinion has been taken to assess the contribution of each profile towards each objective using FST. Utilizing the weightings of the objectives and the contribution of each profile towards each objective and subsequently making dominance matrices, preferred strategies for achieving the different manufacturing flexibilities under various situations of optimism, pessimism and realism were selected. Results of qualitative modeling, which are in fact an outcome of opinion of the experts, taken in structured way depict the relative impact of technology and sourcing based approaches in achieving the different tactical and strategic level manufacturing flexibilities.

Chapter VII covers the summary of the research work, its results, conclusions, and the recommendations. Further, the major learning's results from the survey and the case studies have been presented. Based on the results and the findings, conclusions have been drawn and recommendations have been made. The limitations along with the scope for future work have been covered in the subsequent sections of this chapter.

1.11 Concluding Remarks

An organized attempt has been made to make this study exhaustive, intensive and broad based as possible, for investigating the role of new technology and sourcing aspects in achieving manufacturing flexibility. However, owing to the stupendous task of covering all the manufacturing organizations in almost all parts of a country, the study has been limited to the manufacturing organizations of North India only. North India is covered by different definitions differently. A broad based view of north India was taken for this study that included the states of Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Delhi, and Union territory of Chandigarh. Parts of Rajasthan, and Uttar Pradesh near the above states were also included. There have been limitations of time and resources, but still, by and large, this study has covered almost all types of manufacturing industries. To the best of my knowledge, this study has not left out any important factor or parameter relating to the impact of new technology and sourcing practices in managing manufacturing flexibility.

Review of the literature is the first logical step in a research effort and the next chapter is devoted to the same.

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 2.1 Association of flexibility types and uncertainty, Gerwin (1987)

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

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 situation 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 product of 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 them 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 2.2 Browne's original taxonomy of flexibility types, (Browne et al., 1984)

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

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)

Flexibility Type	Definition
Material	*"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."*
Program	*"the ability of the system to run virtually unattended for a long enough period."*
Market	*"the ease with which the manufacturing system can adapt to a changing market environment.".*

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

Level	Manufacturing flexibility Dimensions	Description	Supporting Literature
Operational Flexibilities (Machine/shop level)	Equipment flexibility	The ability of a machine to switch among different types of operations without prohibitive effort	Browne *et al.* 1984; Carter 1986
	Material flexibility	The ability of equipment to handle variations in key dimensional and metallurgical properties of inputs.	Gerwin 1987,1993
	Routing flexibility	The ability to vary machine visitation sequences for processing a part	Browne *et al.* 1984; Gerwin 1987,1993
	Material handling flexibility	The ability of the material handling system to move material through the plant effectively	Sethi and Sethi 1990; Gupta and Somers, 1992
	Program flexibility	The ability of equipment to run unattended for long periods of time	Sethi and Sethi 1990; Gupta and Somers, 1992
	Process flexibility	Ability of manufacturing system to adapt to changes in production process including to change sequence of steps through which product must progress	Gerwin 1987;Sethi and Sethi 1990 and Sarker *et al.* 1994
Tactical Flexibilities (Plant level)	Mix flexibility	The ability of a manufacturing system to switch between different products in the product mix	Browne *et al.* 1984; Gerwin 1993; Gupta and Somers, 1996
	Volume flexibility	The ability of the manufacturing system to vary aggregate production volume economically	Slack,1983; Browne *et al.* 1984; Sethi and Sethi 1990; Pagell and Krause ,2004
	Modification flexibility	The ability of the manufacturing process to customize products through minor design modifications without incurring high transition penalties or large changes in performance outcomes.	Gerwin 1993, Koste and Malhotra, 1999
Strategic Flexibilities (Organizational level)	New product flexibility	The ability of the manufacturing system to introduce and manufacture new parts and products	Browne *et al.* 1984; Gerwin 1987,1993; Taymaz, 1989; Gupta and Somers, 1996
	Market flexibility	The ability of the manufacturing system to rapidly respond to or influence market changes	Sethi and Sethi 1990; Gerwin 1993
	Delivery flexibility (Strategic aspect)	The ability of manufacturing system to enables the rapid delivery of innovative, customized products and services for new market creation	Narasimhan and Das, 2000; Pagell and Krause , 2004.
	Sourcing flexibility	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	Kumar *et al.*, 2006

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) explicated 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 country 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 (Zammamuto 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 necessicity 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 consider 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.

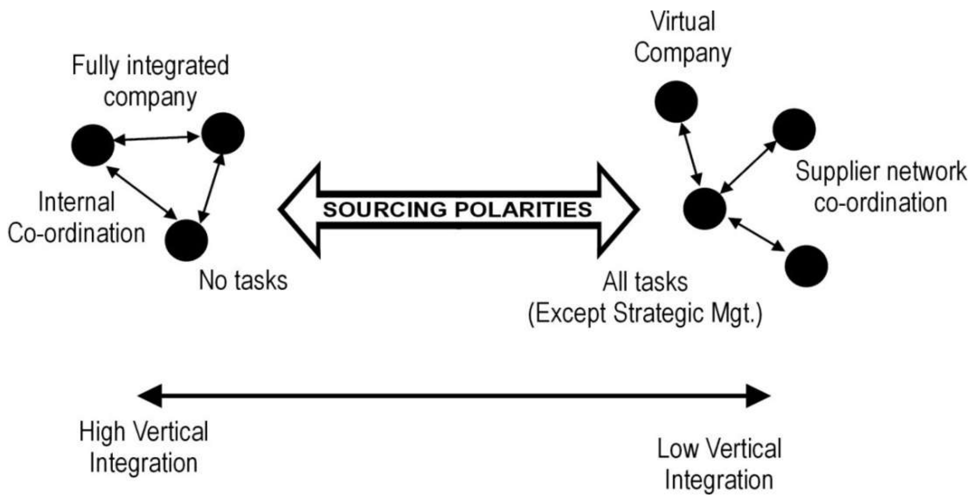


Figure 2.1 The extremes of the sourcing decision

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:

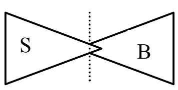
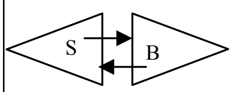
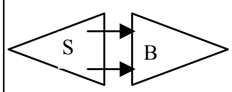
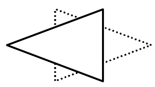
- Make-or-Buy,
- Outsourcing,
- Insourcing
- Strategic sourcing

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)

Sourcing Strategy	Make-or-buy	Outsourcing	Insourcing	Strategic sourcing
Type of Supplier	Component suppliers	Capacity Suppliers	Technology Suppliers	System Suppliers
Main motives	- Cost reduction - Access to residual competencies - Flexibility through capacity extension - Maximization of capacity utilization - Gains through economics 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(MRPII) - Enterprise resource planning(ERP)	- Daily Exchange of information - Internet/ Intranet/ Email - Manufacturing resource planning(MRPII) - 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 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 co-operation	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 - open architecture	Medium - semi-closed architecture	High - semi-closed architecture	Very high - 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 2.6 Summary of literatures addressing sourcing practices and supplier selection issues

Author(s)	Major Findings
Watts and Hahn (1993)	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.
Choi and Hartley (1996)	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.
Narasimhan and Jayaram (1998)	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.
Tan, Handfield, and Krause (1998)	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.

Carr and Pearson (1999)	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.
Narasimhan and Das (1999)	Strategic sourcing can be used to target specific manufacturing flexibilities and that interflexibility synergies need to be considered while formulating flexibility-based manufacturing strategies.
Carr and Smeltzer (2000)	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.
Narasimhan and Das (2000)	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.
Krsuse, Scannell, and Calantone (2000)	Direct involvement activities, where the buying firm internalizes a significant amount of the supplier development effort, play a critical role in performance improvement.
Tracey and Tan (2001)	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.
Carr& Pearson (2002)	Purchasing/supplier involvement has a positive impact on strategic purchasing, and strategic purchasing has a positive impact on firm's financial performance.
Tan (2002)	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.
Tan, Lyman, and Wisner (2002)	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.
Rozemeijer, Weele, and Weggeman (2003)	Corporate purchasing initiatives should be congruent with the overall level of corporate coherence and the level of maturity of the purchasing function.
Modi and Mabert (2007)	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.

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.

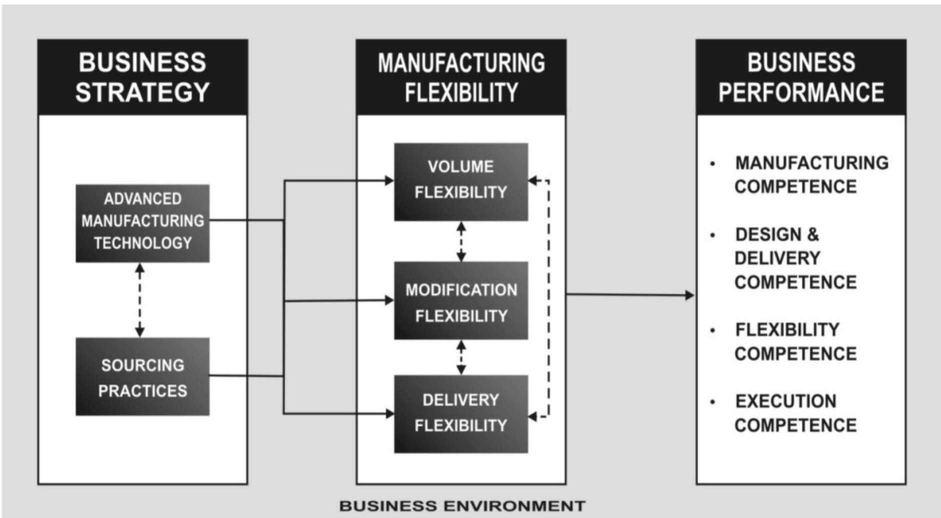


Figure 2.2 A conceptual framework showing the interlinkages between flexibility, technology and sourcing aspects.

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.

CHAPTER III
DESIGN OF THE STUDY

3.1 Introduction

This chapter introduces overall design of study, which includes the methodology adopted for carrying out the research work and various phases of this research. Besides, it contains the details of work done in each phase; and tools, techniques and models used in this research work.

3.2 Research Methodology

This study has been carried out with the purpose of developing effective strategies for the management of manufacturing flexibility in Indian manufacturing industries. Taking into view the complexity of the theme, and the fact that such studies can be carried out primarily by closely treading and analyzing the approaches adopted by various organizations and results thereof, it was considered appropriate to carry out the study under the overall framework of 'flexible systems methodology'.

According to flexible system methodology, problem situations can be handled with two possible philosophies at the extremes, i.e., isolationist, and situational. According to the isolationist philosophy, the best approach is to be developed which will be useful in all possible problem situations. On the other hand, a situational philosophy believes in developing a unique approach for each problem situation. Both these philosophies have shown some success but have some limitations too. The isolationist view is bogged down with the development of a grand paradigm which is an ideal one and difficult to achieve. Similarly, developing a unique approach for each problem situation is very time-consuming and, thus, is not a practical proposition.

The philosophy, which lies in between these two extremes, is of flexibility. Getting attached to a point on the continuum cannot generate the flexibility in the systemic sense. The flexibility is generated by virtue of existence of the continuum. The success lies in making a dynamic balance between the polar extremes, which is the basis of a flexible system methodology. According to this, there are multiple ways of reaching the same end and the suitability of way(s) will depend upon the nature and attributes of the problem situation at hand. It does not advocate the invention of a new approach for each problem situation, but selects an approach out of the existing ones, so as to match the requirements of a problem situation.

The flexible system methodology tries to resolve the end of continuum paradoxes, as it is based on a spectral paradigm, treating all of the systems-based methodologies and techniques as lying on a continuum ranging from hard to soft, and all problem situations also on a continuum ranging from well structured to unstructured. This methodology uses the philosophy of integration of qualitative and quantitative techniques to cater to the diverse requirements of a problem situation and a management process, in a flexible manner.

The three basic components that define the 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 as shown in figure 3.1. The problem is conceptualized as a SAP – LAP (Situation - Actor - Process – Learnings - Action - Performance) paradigm (Sushil; 1997, 1999, 2000).

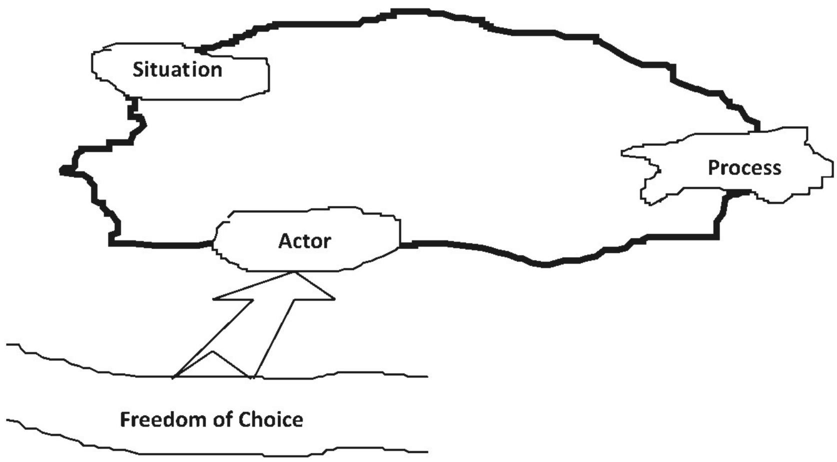


Figure 3.1 Flexible systems management paradigm

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. In this framework, the 'situation' aspect comprises of the present industrial situation in manufacturing industry, whereas the organization constitutes the 'actor' aspects. The role of new technology vis-à-vis sourcing practices in managing manufacturing flexibilities constitutes the 'process'. The actor has various options to exercise, depending upon the situation and process, which forms his 'freedom of choice'.

Based on SAP, key learnings of a case are synthesized, actions suggested and expected performances are summarized. According to Sushil (2001), SAP-LAP types are categorized according to various facets. An attempt has been made in this thesis to present SAP-LAP analysis of following types for various case studies.

- Application focus: Since manufacturing flexibility is a generic area for application and study, the context of all sectors of manufacturing industries, the SAP-LAP analysis is also generic.
- The analysis is atomic or naive one as it does not take into consideration, interaction and inter-dependence of six basic components of SAP-LAP.
- Though in case studies historical context, performance indicators and milestones of various firms have been briefly discussed over the time span, yet a snap shot of various practices and process followed for managing manufacturing flexibility has been taken, therefore, the SAP-LAP analysis is static.
- Since only one systematic framework representing the approaches for managing manufacturing flexibility has been developed, the SAP-LAP analysis – on which this framework is partly based – is singular.

3.3 Phases of Research

The study has been carried out with the purpose to assess the impact of new technology and sourcing practices on different manufacturing flexibilities. Based on the flexible system methodology, the research work has been divided into following phases, details of which are presented in figure 3.2.

Phase I Clarifying the Context

Phase II Understanding and Assessing the Situation

Phase III Assessing the Actor's Capability

Phase IV Evolving a Management Process

Phase V Developing an Implementation Plan

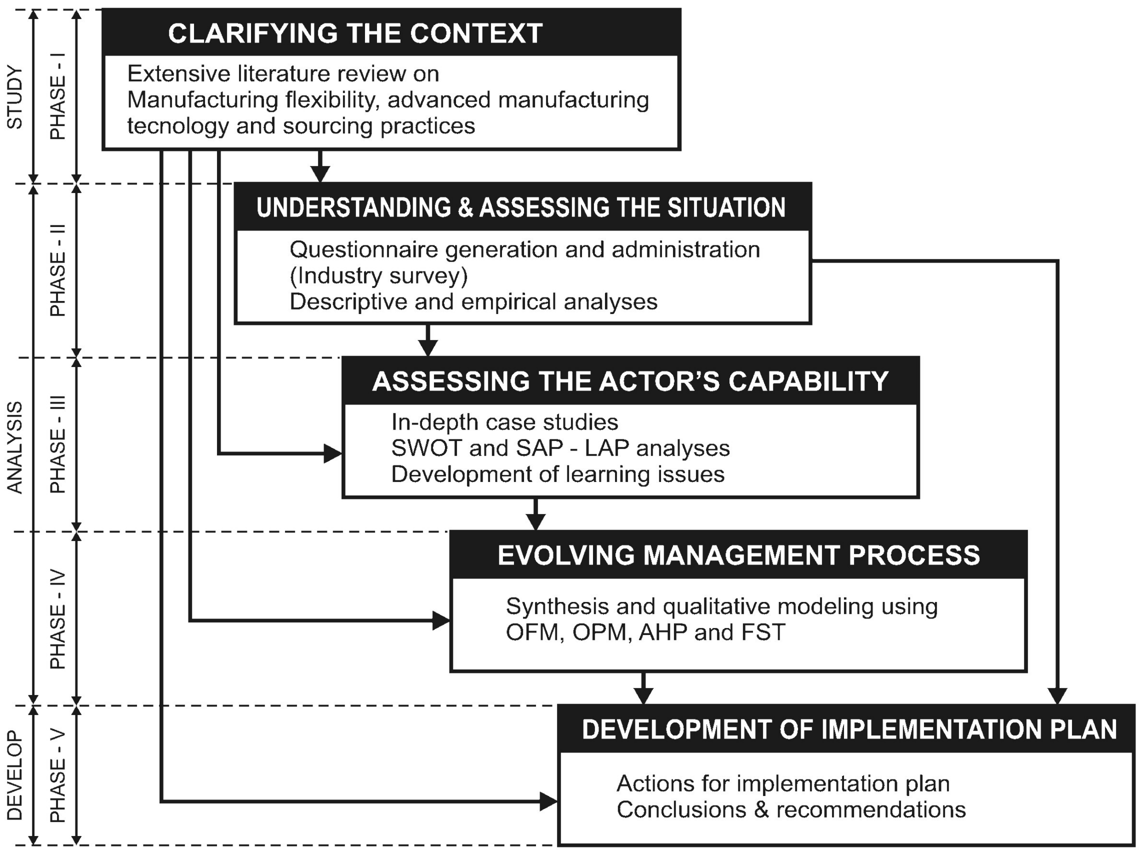


Figure 3.2 Design of the study

3.3.1 Clarifying the Context

The literature on the nature, types and levels of manufacturing flexibility has been explored in detail. This has essentially focused on the management of the new technology and sourcing practices as a way to achieve the manufacturing flexibilities at various levels. In depth literature review has been conducted to explore the past implementation of new technology and sourcing practices for achieving different manufacturing flexibilities. Literature review of the economic, technical, environment and other related issues regarding implementation of new technology and sourcing practices in manufacturing enterprises for achieving the manufacturing flexibility has also been explicated. Case studies have been reviewed to apprise of the results achieved by different researchers in different situations.

3.3.2 Understanding and Assessing the Situation

Churchill (1995) provides an overview of the different types of survey-based research as shown in figure 3.3. Cross-sectional research is primarily used to measure the various characteristics once, whereas longitudinal research considers the measurement over time. Furthermore, cross-sectional research involves a sample of elements from the population of interest, whereas true and omnibus panels are used in longitudinal research. Even though longitudinal research could be useful in observing manufacturing flexibility over time, there are some critical drawbacks to this method. The main disadvantage of panels is that they are non-representative. Furthermore, the agreement to participate involves a far-reaching commitment of the respondent, which is very difficult to achieve. Instead, the use of cross-sectional research is far more useful in this study and is considered the most important type of survey-based research as measured by the number of times it is used as compared to other methods. First of all, cross-sectional research provides a snapshot of the variables of interest at a single point in time. Second, the sample of elements selected is considered to be representative of some known universe.

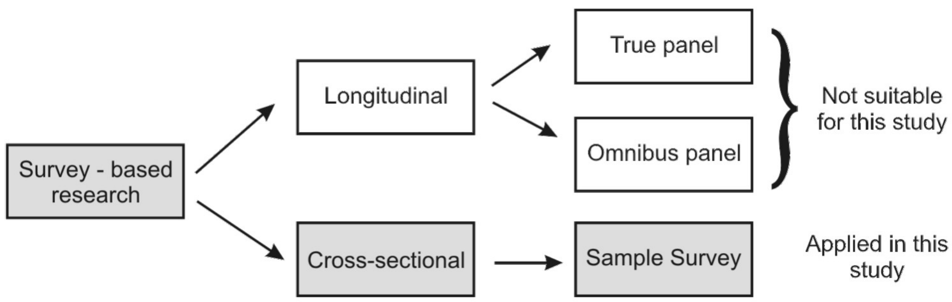


Figure 3.3 Overview of survey based research

Survey methodology: A survey of various manufacturing organizations, involved in achieving manufacturing flexibilities at tactical and strategic level has been taken up by using a peculiarly designed questionnaire. Special emphasis has been given to seek information related to business strategy and performance of the organizations, status of volume, modification delivery and manufacturing flexibility and the role of technology and sourcing practices in achieving flexibility at tactical and strategic level. The questionnaire has been designed after extensive literature review and validated through peer review from academicians, consultants and practitioners from the industry. In the questionnaire, objective type questions containing multiple choice answers were framed on all aspects of manufacturing flexibility and the impact of new technology and sourcing practices in managing it. The questionnaire was duly pre-tested on a representative sample of the industry. The survey has primarily been conducted through mail but personal visits have also been undertaken to the extent possible.

Descriptive analyses: The descriptive analyses for the various research parameters have been carried out to assess their present status in the manufacturing organizations. Present level of manufacturing flexibility has been determined by assessing the planning and implementation procedures adopted. Study of relationship between new technology-flexibility and sourcing- flexibility relationship has been explored and explicated in the study. The organization competitiveness, responsiveness and involvement to change have also been analyzed in context with the study. The content validity was assessed through the interviews carried out with the respondents (face validity). Generally, respondents' understanding of the questions was similar within and across the sections. Most importantly, they understood the information that the questions were designed to obtain.

Empirical analyses: The primary interest in data analysis is to investigate theinfluence of sourcing practices, advanced manufacturing technology on manufacturingflexibilities, and focused on the technology-sourcing-flexibility association. In data analysis, independent and dependent variables have been formulated based on literature review and the objectives of this research. Constructs (variables) relating to manufacturing flexibilities categorized as dependent variables and sourcing practices and advanced manufacturing technologies categorized as independent variables have been used in the analysis. Individual item measures have been developed posited to impact manufacturing flexibility for these constructs in the study. Five distinct sourcing practices construct that are likely to influence the pursuing manufacturing flexibility objectives includes supplier involvement in managing volume changes requests, supplier involvement in modifying products, supplier involvement in delivery changes request, supplier competencies and supplier relationship. Further, advanced manufacturing technology based constructs comprise of manufacturing technology, manufacturing design and manufacturing infrastructure. The effect of these factors on volume, modification and delivery flexibility has been assessed.

The convergent and discriminant validity of the constructs and their measures have been done and various statistical tools and techniques have been employed using SPSS software to predict the results. Convergent validity assesses the degree to which two measures of same concept are correlated. It is assessed by the correlation among items which make up the scale or instrument measuring a construct (internal consistency validity), by the correlation of the given scale with measures of the same construct. Discriminant validity, the second major type of construct validity, refers to the principle that the indicators for different constructs should not be so highly correlated as to lead one to conclude that they measure the same thing. This would happen if there is definitional overlap between constructs.

Since our interest centered on investigating the relationships between a set of multiple dependent and multiple independent variables with little prior knowledge of such relationships, canonical correlation analysis was deemed the appropriate multivariate statistical technique (Hair *et al.* 1998) to use. The inherent flexibility of canonical correlation in terms of the number and types of variables handled, both dependent and independent, makes it a logical candidate for many of the more complex problems addressed with multivariate techniques. The first step of canonical correlation analysis is to derive one or more canonical functions. Each function consists of a pair of variates, one representing the independent variables and the other representing the dependent variables. Out of these, one set of variate is selected based on three criteria, these are: sets having maximum canonical correlation, significant f value and highest redundancy index.

Generally, the first set of variates satisfies these conditions and is used for further analysis. Further, computation of canonical cross-loadings has been done, as a direct measure of the dependent–independent variable relationships by eliminating an intermediate step involved in conventional loadings.

As a predecessor to canonical correlation analysis, the pair-wise correlations between variables were examined and variables were selected to avoid problems of multicollinearity. For a closer examination of relationships between individual dimensions of dependent variables with the independent variables, the multiple regression analyses are done.

3.3.3 Assessing the Actor's Capability

The survey has been followed by case studies in some industrial units. The purpose of the case studies has been to analyze those aspects of management of manufacturing flexibility which have been reflected as the potential areas requiring further investigation. The case studies have been analyzed and their results have depicted the total industrial scenario about the status of manufacturing flexibilities and assessed the relative impact of sourcing practices and new technology on different flexibilities. The preliminary information provided by the survey has been authenticated by these case studies and the synthesis of the two has provided the required results. To carry out case studies, the basis for selection of organizations has been:

i. The organizations to be a representative of the manufacturing industry i.e. most of the operations and process are prevalent in that organization.

ii. It has requisite activity going on pertaining to the adoption of new technology and sourcing aspects for managing manufacturing flexibilities as reflected by the results of the survey.

iii. The organization is forthcoming and cooperative for conducting case studies.

The methodology adopted for conducting the case studies has been shown in figure 3.4.

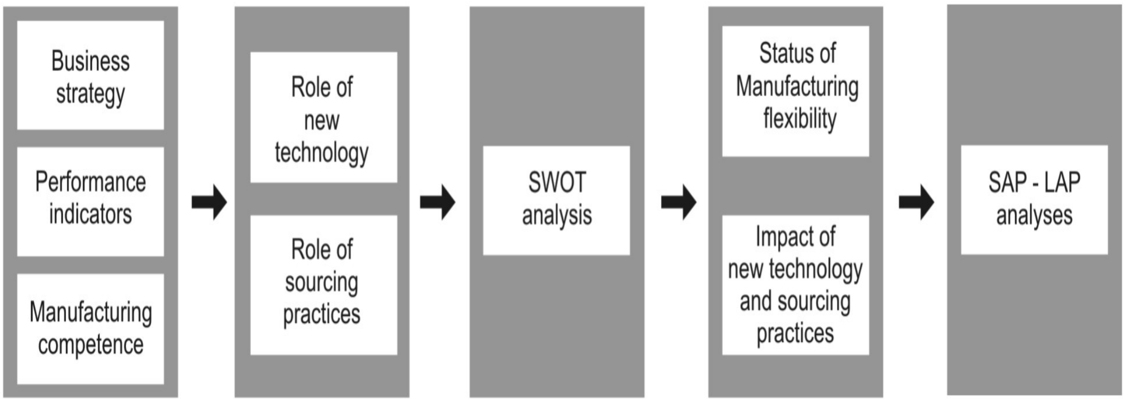


Figure 3.4 Methodology for conducting the case studies

Details of these steps, techniques and their justification are described in Table 3.1.

Table 3.1 Analysis and justification of case study methodology

Sr. No.	Steps of Analysis and Technique(s) Used	Justification of the Techniques
1	**Step-I:** Collection of data and information from the company regarding various performance indicators and the measures undertaken from time to time. Techniques used: Personal interactions, Observations, Scanning the published annual reports and other printed material.	This information is necessary for such studies and all the three techniques used are the proven effective methods.
2	**Step-II:** Review of performance indicators like net sales, profit after tax, EBIDTA, earnings per share etc.	To study the trends of these indicators over time as a measure of the organization business competitiveness and growth.
3	**Step-III:** Status and analysis of the practices followed by the organization for managing manufacturing flexibility. Techniques used: Consolidating the role of new technology and sourcing practices and assessing the strategy adopted by the organization.	To study and analyze the impact of various practices followed by the company for achieving manufacturing flexibility.
4	**Step-IV :** Learnings from the case studies Techniques used: SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, SAP (Situation, Actor, Process) analysis, LAP (Learning, Action, Performance) Synthesis	Strategies adopted by the organizations for managing manufacturing flexibility to be seen in the light of their strengths, weaknesses, opportunities and threats (SWOT). SAP analysis consolidates the processes adopted by the actors under various situations while LAP synthesis brings out learning’s from the approaches, actions and performance.

3.3.4 Evolving Management Process

The learning issues of survey and case studies have been synthesized to come out with an implementation plan. For this, a qualitative modeling technique has been applied using Options Field Methodology (OFM), Options Profile Methodology (OPM) proposed by Warfield (1982), Analytic Hierarchy Process (AHP) developed by Saaty (1980) and Fuzzy Set Theory (FST) developed by Zadeh (1965). Various options have been derived from the synthesized learning issues and the modeling has been done in the following manner.

Various options have been derived from the synthesized learning issues and the modeling has been done in the following manner.

Step I - OFM

i. Listing of various options as solutions.
ii. Making categories from options.
iii. Deciding dimensions of the problem and including categories in these dimensions.
iv. Clustering of dimensions.
v. Ordering of clusters.
vi. Ordering of dimensions within clusters.

Step II - OPM

i. Making various profiles as a solution to the problem.
ii. Drawing tie line and allocating various options to the profiles.

Step III - AHP

i. Listing various criteria as objectives.
ii. Doing paired comparison of objectives and assigning numerical values.
iii. Calculating weighted sum of objectives by Eigen Vector.
iv. Finding comparative contribution of each profile towards each objective and quantifying it.

Step IV - FST

i. Finding out optimistic, pessimistic and average position matrix.
ii. Making dominance matrix.
iii. Ranking the profiles.

iv. Finding out different approaches to achieve the objectives with varying degree of optimism.

3.3.5 Developing Implementation Plan

Based upon the outcome of Hadley's matrix of cautions optimism for dominance matrices employing optimism, average, pessimism and cautious optimism approaches, preferred strategies has been evolved for achieving volume, modification and delivery flexibility.

Finally, the critical learning issues from survey and case studies have been synthesized and utilized in the domain of a qualitative model to develop a systematic plan for technology-sourcing-flexibility framework for achieving manufacturing flexibilities. In view of the insights gained from this synthesis and the literature available, the actions for implementation in the manufacturing industry have been recommended.

3.4 Questionnaire Development

For effectively conducting the survey, the first task was to design a questionnaire. A relevant and comprehensive questionnaire containing around 160 simple questions pertaining to the desired conceptual framework was designed. Information on various aspects related to this research work in the Indian manufacturing industry was sought in it. The questionnaire was designed after extensive literature review and validated through peer reviews from academicians, consultants and practitioners from the industry. A five point (1–5) Likert-type scale has been employed for all item measures in the questionnaire. All the questions are of multiple choices and close ended on a scale. The questionnaire has been divided into five sections i.e. Section A, B, C, D and E pertaining to research objectives and issues. Scale items were used in the analysis, since the research interest was to examine the effects of independent variables on dependent variables as discussed in a next chapter. This approach is consistent with previous research studies, which employ single scale items for various variables (Ettlie and Penner-Hahn 1994, Suarez *et al.* 1996, Gupta and Somers 1996). Before finalizing the questionnaire, a methodical review of all the items and instructions was undertaken. The covering letter and the questionnaire is given as Appendix-A.

3.5 Canonical Correlation Analysis

The primary objective of data analysis in this research work is to examine the relationship between independent and dependant variables. Since the interest centered on investigating the relationships between a set of multiple dependent and multiple independent variables with little prior knowledge of such relationships, canonical correlation analysis has been considered to be the most appropriate and powerful multivariate statistical technique (Hair *et al.* 1998) to use. The inherent flexibility of canonical correlation in terms of the number and types of variables handled, both dependent and independent, makes it a logical candidate for many of the more complex problems addressed with multivariate techniques. Canonical correlation analysis deals with the association between composites of sets of multiple dependent and independent variables. In doing so, it develops a number of independent canonical functions that maximize the correlation between the linear composites, also known as canonical variates, which are sets of dependent and independent variables. Each canonical function is actually based on the correlation between two canonical variates, one variate for the dependent variables and one for the independent variables. Another unique feature of canonical correlation is that the variates are derived to maximize their correlation. Moreover, canonical correlation does not stop with the derivation of a single relationship between the sets of variables. Instead, a number of canonical functions (pairs of canonical variates) may be derived.

The issues of the impact of sample size (both small and large) and the necessity for a sufficient number of observations per variable are frequently encountered in canonical correlation. Researchers are tempted to include many variables in both the independent and dependent variable set, not realizing the implications for sample size. Sample sizes that are very small will not represent the correlations well, thus obscuring any meaningful relationships. Very large samples will have a tendency to indicate statistical significance in all instances, even where practical significance is not indicated. The researchers are encouraged to maintain at least 10 observations per variable to avoid “overfitting” data.

The classification of variables as dependent or independent is of little importance for the statistical estimation of the canonical functions, because canonical correlation analysis weights both variates to maximize the correlation and places no particular emphasis on either variate. Yet, because the technique produces variates to maximize the correlation between them, a variable in either set relates to all other variables in both sets. This allows the addition or deletion of a single variable to affect the entire solution, particularly the other variate. The composition of each variate, either independent or dependent, becomes critical.

As a precursor to canonical correlation analysis, the pair-wise correlations between variables are examined and among two highly correlated variables, one has to be dropped to avoid problem of multicollinearity.

The first step of canonical correlation analysis is to derive canonical functions. Each function consists of a pair of variates, one representing the independent variables and the other representing the dependent variables. The maximum number of canonical variates (functions) that can be extracted from the sets of variables equals the number of variables in the smallest data set, independent or dependent. As in this research work, seven independent variables and three dependent variables have been considered for canonical correlation analyses; three canonical variates have been derived.

The derivation of successive canonical variates is similar to the procedure used with unrotated factor analysis. The first factor extracted accounts for the maximum amount of variance in the set of variables, then the second factor is computed so that it accounts for as much as possible of the variance not accounted for by the first factor, and so forth, until all factors have been extracted. Therefore, successive factors are derived from residual or leftover variance from earlier factors. Canonical correlation analysis follows a similar procedure but focuses on accounting for the maximum amount of the relationship between the two sets of variables, rather than within a single set. The result is that the first pair of canonical variates is derived so as to have the highest inter-correlation possible between the two sets of variables. The second pair of canonical variates is then derived so that it exhibits the maximum relationship between the two sets of variables (variates) not accounted for by the first pair of variates. In short, successive pairs of canonical variates are based on residual variance, and their respective canonical correlations (which reflect the interrelationships between the variates) become smaller as each additional function is extracted. That is, the first pair of canonical variates exhibits the highest inter-correlation, the next pair the second-highest correlation, and so forth. One additional point about the derivation of canonical variates: as noted, successive pairs of canonical variates are based on residual variance. Therefore, each of the pairs of variates is orthogonal and independent of all other variates derived from the same set of data. Out of these, one set of variate is selected on the basis of three criteria, these are: sets having maximum canonical correlation, significant f value and highest redundancy index. As such, the redundancy measure is perfectly analogous to multiple regressions' R^2 statistic, and its value as an index is similar. The calculation of the redundancy index is a three step process. The first step involves calculating the amount of shared variance from the set of dependent variables included in the dependent canonical variate. The second step involves calculating the amount of variance in the dependent canonical variate that can be explained by the independent canonical variate. The final step is to calculate the redundancy index, found by multiplying these two components. To have a high redundancy index, one must have a high canonical correlation and a high degree of shared variance explained by the dependent variate. A high canonical correlation alone does not ensure a valuable canonical function. Redundancy indices are calculated for both the dependent and the independent variates, although in most instances the researcher is concerned only with the variance extracted from the dependent variable set, which provides a much more realistic measure of the predictive ability of canonical relationships.

Canonical loadings measure the simple linear correlation between an original observed variable in the dependent or independent set and the set's canonical variate. The canonical loading reflects the variance that the observed variable shares with the canonical variate and can be interpreted like a factor loading in assessing the relative contribution of each variable to each canonical function. The methodology considers each independent canonical function separately and computes the within-set variable-to-variate correlation. The larger the coefficient, the more important it is in deriving the canonical variate. Also, the criteria for determining the significance of canonical structure correlations are the same as with factor loadings in factor analysis.

The computation of canonical cross-loadings has been suggested as an improved method to interpret the results in canonical correlation analysis as compared to canonical weights or canonical loadings (Hair *et al*., 1998). This procedure involves correlating each of the original observed independent variables directly with the dependent canonical variate, and vice versa. The conventional loadings correlate the original observed variables with their respective variates after the two canonical variates are maximally correlated with each other. This may also seem similar to multiple regression analysis, but it differs in that each independent variable, for example, is correlated with the dependent variate instead of a single dependent variable. Thus cross-loadings provide a more direct measure of the dependent–independent variable relationships by eliminating an intermediate step involved in conventional loadings. Generally the first set of variates satisfies these conditions and is used for interpretation.

3.6 Multiple Regression Analyses

For a closer examination of relationships between individual dimensions of dependent variables with the independent variables, the multiple regression analyses are done. Multiple regression analysis is a statistical technique that can be used to analyze the relationship between a single dependent variable and several independent variables.

There are different ways that the relative contribution of each predictor variable can be assessed. Enter and Stepwise method has been used for the empirical data analyses in this work. In the "simultaneous" method (which SPSS calls the Enter method), the researcher specifies the set of predictor variables that make up the model. The success of this model in predicting the criterion variable is then assessed. Stepwise approach examines the contribution of each independent variable to the regression model. Each variable is considered for inclusion prior to developing the equation. The independent variable with the greatest contribution is added first. Other independent variables are then selected for inclusion based on their incremental contribution over the variable(s) already in equation.

3.7 Concluding Remarks

In this chapter, the methodology adopted along with the step-by-step approach employed for the research has been elaborated. Flexible System Methodology has been used as a tool to help evolve the problem in a Situation, Actor and Process (S-A-P) interplay. Empirical studies yield rich data for statistical analysis that can be used for drawing relevant inferences. Case studies provide deep insight to the problem by giving real picture of the industrial situation. Synthesis of the learning issues of both empirical studies and case studies help evolve a management process by using qualitative methods like Option Field / Profile Methodology (OFM/OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST). An implementation plan has been suggested to manage the industrial situations.

CHAPTER IV

SURVEY BASED RESEARCH RESULTS

4.1 Introduction

In this chapter the survey-based research results conducted in medium and large scale manufacturing organizations of the northern region of India covering the states of Punjab, Haryana, Himachal Pradesh, Rajasthan, Uttar Pradesh, Delhi and Union Territory of Chandigarh have been discussed, analyzed and presented. The survey was conducted in the manufacturing organizations that are in the process of achieving the manufacturing flexibility at all or various levels by acquiring, developing or utilizing the advanced manufacturing technology or by the use of specific/different sourcing practices. The objective of the survey has been to assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

4.2 Questionnaire Development

For conducting the survey, the first task was to design a questionnaire. A simple, relevant and comprehensive questionnaire containing around 160 questions was peculiarly designed, which seeks information on the status of different dimensions of manufacturing flexibility and various methods for achieving it in the Indian manufacturing industry. Special emphasis was given to seek information related to business strategy and performance of the organizations, status of volume, modification, delivery and manufacturing flexibility and the role of technology and sourcing practices in achieving flexibility at tactical and strategic level. The questionnaire was designed after extensive literature review and validated through peer review from academicians and practitioners from the industry. A 1- 5 Likert-type scales was employed for all item measures in the questionnaire. All the questions are of multiple choices and close ended on a scale. The questionnaire has been divided into five sections i.e. Section A, B, C, D and E.

Section A has been framed to get general information about the responding organization e.g. type of organization, details of collaborations, products manufactured, percentage of market share, number of employees, scale, present turnover and net profit.

Section B seeks detailed information related to the business strategy and performance of the responding organization. This section also includes the importance of various business initiatives and competitive priorities for the organizations.

Section C has been designed to get the detailed information about the status of volume, modification, delivery and manufacturing flexibility and the role of various practices in achieving it.

Section D seeks detailed and comprehensive information regarding the status of new technology for the organizations. It includes the importance, level and barriers for adopting new technology by the organizations. Information has been gathered for assessing the level of change in the performance objectives i.e. product quality, different flexibilities, cost, delivery and profit as a result of adopting the new technology.

Section E has been designed to study the role of various sourcing practices in managing manufacturing flexibilities at tactical and strategic level. Data has been gathered for analyzing the role of sourcing practices in managing various competitive priorities for the organizations, supplier involvement in managing market fluctuations, supplier selection criteria, buyer-supplier management orientation and flexibility of supplier in managing market fluctuations. Furthermore, the level of change in the performance objectives i.e. product quality, dimensions of manufacturing flexibility, cost, delivery, profit and the effect on market share due to the implementation of various supplier based sourcing practices for the organization has been studied and analyzed. Finally, the data on level of dependency on sourcing practices and adoption of new technology has been sought for managing the volume, modification and delivery flexibility.

4.2.1 Questionnaire Pre-testing

To ensure the relevance and the effectiveness of the questions to the manufacturing industry, the questionnaire was pre-tested on a representative sample of industry. The suggestions of peers, senior executives from the industries and academicians were incorporated to make the questionnaire relevant to the purpose so that it may bring out key outcomes. The objective has been to confirm that responses were based on correct interpretations of the questions. A high degree of consistency was found in the responses of manufacturing and engineering executives to the questionnaire items. The qualitative feedback provided was very helpful in the preliminary efforts to assess the reliability of the scales. The coefficient alpha (Cronbach, 1951) was assessed for each scale item as well as the item-to-total correlation for the empirical analysis. Before finalizing the questionnaire, a methodical review of all the items and scales was undertaken. The details of the cover letter and the resulting questionnaire are given in Appendix - A. The questionnaire served the purpose of revealing the exploits of Indian entrepreneurs with the implementation of new technology and sourcing practices and highlighted its contributions in managing manufacturing flexibilities.

4.3 Conducting the Survey and Response

To collect the necessary data, the questionnaire was send to a convenience sample (n=400), which has been selected from the large and medium scale organization members chosen at random from the membership of the Confederation of Indian Industry (CII) and Automotive Component Manufacturers Association of India (ACMA). Each questionnaire was sent personally to the respondent after a short inquiry in which the person was asked to participate. This technique additionally offered the opportunity to verify the respondent's data. A reminder with a duplicate survey was sent to all non-respondents to the initial mailing. Sixty-eight responses were received, constituting a response rate of 17%. This compares well with the response rates for studies in operations management (Handfield 1994, Suarez *et al.* 1996). Elimination of unusable or incomplete responses resulted in 60 cases.

4.3.1 Type of Organizations

The focus of the study is on large and medium-scale manufacturing enterprises of north India. The data collected for the present research involves 34 responses from large scale and 26 responses from medium scale organizations and shown in figure 4.1.

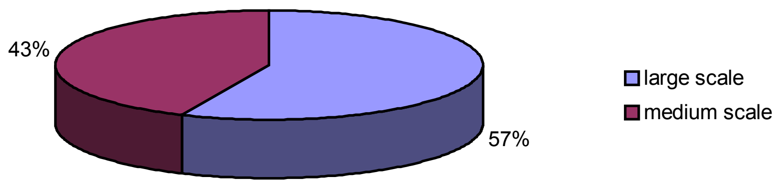


Figure 4.1 Type of organization

As per Government of India categorization, a large-scale manufacturing enterprise in India is defined as an industrial undertaking in which the investment in fixed assets (plants and machinery), whether held on ownership term or lease or on hire/ purchase, exceed Rs. 100 crore. For medium-scale enterprises, the range is between Rs. 1–100 crore in fixed assets.

4.3.2 Breakup of Responses

The breakup of responses from the manufacturing organizations comprises automobile and heavy earth-moving machinery manufacturing organizations (17), mechanical sub-assembly manufacturing organizations – pistons, pumps, engines, steering linkages, etc. (26), electrical and electronics machinery manufacturing organizations (10) and process industries (7). The industry-wise breakup is shown in figure 4.2. The targeted respondents for this study are believed to be 'very knowledgeable' about the production, operations and supply chain management policies of an organization.

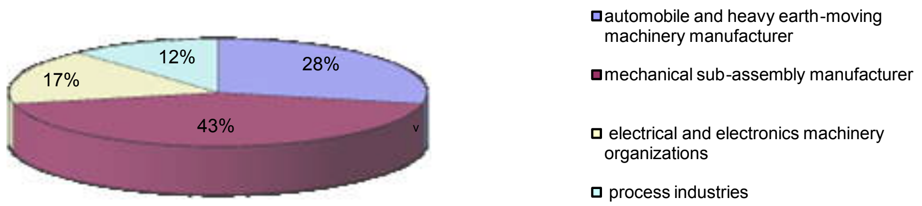


Figure 4.2 Industry-wise breakup of responses

4.3.3 Spread of Knowledge Level

A summary of the respondent's knowledge level is presented in figure 4.3.

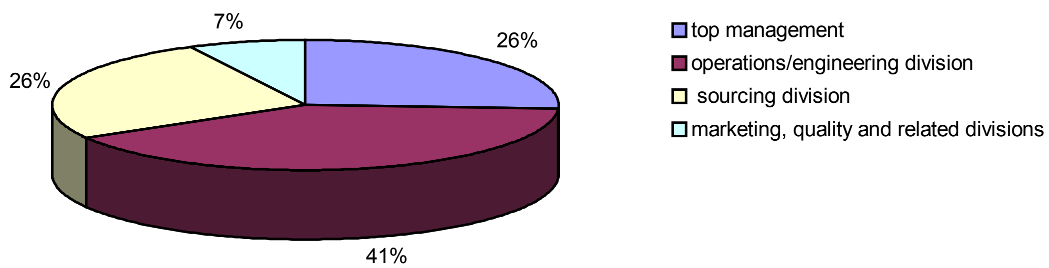


Figure 4.3 Spread of knowledge level

The majority of the respondents were either from the top management/ general manager of the organization (14), senior manager in sourcing (14) and operations/engineering division (22) as they are in best position to answer the questions of this survey because of their experience, expertise, and access to operational and strategic policies and data. Furthermore, a limited number of respondents had other functional orientations such as marketing, quality and related areas (4).

4.3.4 Turnover

The data has been gathered concerning the present turnover of the organizations so as to estimate the volume of business being carried by the respondent organization. Out of 60 responses, the 13% organizations have annual turnover of less than Rs.50 crore, 23% between 50-100 crore, another 13% having in between 100 to 250 crore, 17% have 250 to 500 crore and remaining 34% have annual turnover of their organization above Rs. 500 crore as depicted in figure 4.4. The figure 4.4 indicates the significant representation of all the segments with turnover ranging from 50 crore to more than 500 crore and implies the inclusion of emergent organizations of the north India in the preview of the study.

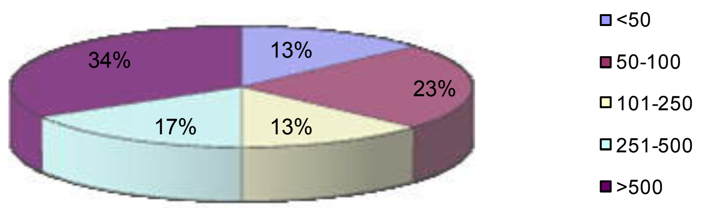


Figure 4.4 Present turnover in crore

4.3.5. Market Share and Net Profit

The data has also been collected for knowing the present market share acquired by the organization and shown in figure 4.5. Market share is the amount of total sales of the products offered by an organization in a particular market and often shown as a percentage, and is a good indicator of performance compared to competitors in the same market sector.

It has been found that 8% of the organizations are having market share less than 10% of the total market, 31% of the organizations are in the range of 10-25%, another 30% of the organizations are in the range of 26-50%, 18% in the range of 51-75% and 13% of the organizations acquire more than 75% of the total market share.

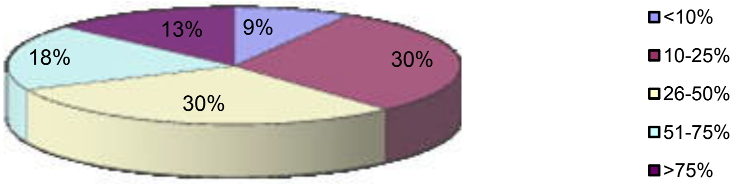


Figure 4.5 Market share of the organizations

Likewise the status of net profit or earnings, indicating the progressive status of organizations has been revealed in the figure 4.6.

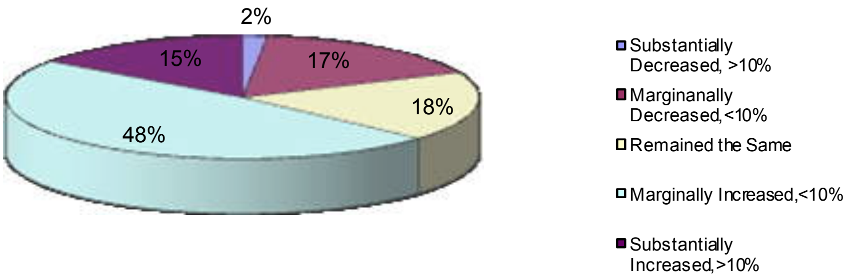


Figure 4.6 Change in net profit of the organizations

The data reveal that merely 2% of total responding organizations have their net profit, substantially decreased (more than 10%) in the last two year of their businesses. 17% of organizations have reported the marginal decrease(less than 10%) in the net profit, however, 18% are maintaining it at the same level. The net profit has marginally increased(less than 10%) in 48% of the organizations and substantially increased (more than 10%) for about 15% of organizations.

Lastly, the profile of organizations in the preview of this study indicates the systematic inclusion of different segments for the type of organization, spread of knowledge level of respondent, present turnover, market share and the net profit. This will comprehensively facilitate in finding out accurately the status of various issues related to the research objective.

4.4 Business Strategy and Performance

The data has been collected and analyzed for understanding and explicating the importance of various business initiatives and competitive priorities adopted as a part of the business strategy by the manufacturing organizations. The importance of customer focus and commitment, organization competitiveness, responsiveness, involvement to change and role of related aspects of infrastructural and structural factors has been explored. Further, the information has been gathered to elucidate and understand the impact of new technology and supplier practices on business performance. The role of various competitive priorities in offering new or significant improved products has also been studied and meticulously described in this section.

4.4.1 Importance of Business Initiatives

The importance of various initiatives related to business strategy as adopted by the organizations have been analyzed and presented in the Table 4.1. Parameters of business initiatives include the 'importance of customer focus and commitment', 'innovation and change', 'commitment to quality', 'manufacturing technology', 'win-win situation with suppliers' and 'flexibility in manufacturing'. The Table 4.1 presents the score (Si) achieved by the organizations in different aspects mentioned in column 2 of the table. The number of organizations (Ni) scoring 1, 2, 3, 4 and 5 points on a 5 point scale ranging from lowest choice to the highest choice have been presented and hence the total points secured by all the 60 organizations in a particular aspect have been calculated and then its percentage score based on the calculation has been made and tabulated in the last column of the Table 4.1.

Table 4.1 Importance of business initiatives

S. No.	Business Initiatives	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Customer focus and commitment	0	0	0	12	48	288	96.00
ii.	Innovation and change	0	0	9	31	20	251	83.67
iii.	Commitment to quality	0	0	4	10	46	282	94.00
iv.	Manufacturing technology	0	1	13	26	20	245	81.67
v.	Win-win situations with suppliers	0	2	13	24	21	244	81.33
vi.	Flexibility in manufacturing	0	3	13	26	18	239	79.67

The 'customer focus and commitment' has been felt as most important initiative among the group with highest score followed by 'commitment to quality'. It has been closely followed by the organizations thrust towards the ‘innovation and change’. The role of ‘manufacturing technology’, ‘win-win situations with suppliers’ and ‘flexibility in manufacturing’ has also been notably and equally targeted by the organizations. The level of score for all the initiatives depicts the fanaticism of the organizations to excel in their businesses.

4.4.2 Significance of Competitive Priorities

Table 4.2 presents the in-depth analysis carried out to determine the significance of different competitive priorities on business performance of the responding organizations. The various aspects of competitive priorities related to quality, delivery, flexibility, cost and technology have been delineated. The result indicates the ‘role of quality conformance’, ‘quality planning and improvement’, ‘reduction in production cost’ and ‘reliable quality at competitive price’ among the important priories for the organizations. ‘Providing fast deliveries’ and ‘reduction in lead-time’, closely follows the quality and cost aspects. Organizations have also felt the importance of inducing flexibility in the manufacturing and design as an instrument for achieving competitiveness. Achieving the manufacturing flexibility in terms of adjusting production capacity quickly, introducing large number of product features and large degree of product variety has been felt considerably important by the organizations. ‘Investment in new technology’ has been treated as a significant tool for achieving the competitive priorities. The least score is with ‘rapid design changes in the product’ in the midst of varied degree of importance for the organizations.

Table 4.2 Significance of competitive priorities

S. No.	Significance of competitive priorities	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i..	Quality planning and improvement	0	1	3	25	31	266	88.67
ii.	Reliable quality at competitive price	0	1	3	23	33	268	89.33
iii..	Quality conformance	0	0	4	14	42	278	92.67
iv.	Provide fast deliveries	1	1	1	31	26	260	86.67
v.	Reduce lead time	1	0	11	27	21	247	82.33
vi.	Adjust production capacity quickly	1	5	8	31	15	234	78.00
vii.	Large number of product features	0	9	9	32	10	223	74.33
viii.	Large degree of product variety	1	5	15	28	11	223	74.33
ix.	Rapid design changes in product	1	14	15	19	11	205	68.33
x.	Reduce production costs	0	1	6	13	40	272	90.67
xi.	Investment in new technology	0	3	14	35	8	228	76.00

4.4.3 Level of Competitiveness Measure

The importance of various competitive factors has been studied for offering new or significantly improved products by the organizations and presented in Table 4.3. 'To reduce the impact of market fluctuations' and 'to gain competitive excellence' has been categorized as highly important factors for offering new or significantly improved products, followed by 'improved production flexibility', 'access to new customers/ new market creation' and 'quality leadership' that has been found to be at the same level.

Table 4.3 Importance of competitive factors for offering new or significantly improved products

S.No.	Importance of competitive factors	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	To reduce the impact of market fluctuations	2	1	9	23	25	248	82.67
ii.	Access to new customers/ new market creation	0	2	11	29	18	243	81.00
iii.	To gain competitive excellence	0	0	9	21	30	261	87.00
iv.	Improved production flexibility	0	1	12	30	17	243	81.00
v.	Quality leadership	0	2	12	30	16	240	80.00

For achieving excellence in business an organization must have an edge over its main competitors for varied performance parameters. These parameters include 'new product introductions', 'product features and varieties', 'quality of product offered', 'flexibility in manufacturing', 'access to new technology' and 'average sales growth'. The level of competitive position of the responded organizations over a period of last two years for different performance parameters have been studied and presented in Table 4.4. The trend shows the substantial improvement in competitive position for the respondent organizations over the last two years of their businesses.

Table 4.4 Competitive position of an organization

S.No.	Performance Parameters	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	New product introductions	0	1	9	27	23	252	84.00
ii.	Product features and varieties	0	2	12	23	23	247	82.33
iii.	Quality of product offered	0	0	10	20	30	260	86.67
iv.	Flexibility in manufacturing	0	1	14	33	12	236	78.67
v.	Access to new technology	0	1	4	38	17	251	83.67
vi.	Average sales growth	0	2	11	21	26	251	83.67

The contribution of each of the performance parameter has been found to be substantially significant, with 'quality of product offered' achieving the highest score in the group. It is closely followed by the 'new product introductions', 'access to new technology', 'average sales growth' and 'product features and varieties' in order of their occurrence. The least yet a significant score is with 'flexibility in manufacturing', indicative of the fact that though organizations have not excelled but have started realizing its importance.

4.5 Status of New / Advanced Manufacturing Technology (AMT)

The overall potential of AMT is immense and several problem issues in design, manufacturing or administrative activities could be solved through increased use of it. Improvements in product quality, manufacturing flexibility, increased profitability, and improvements in productivity due to a reduction in the rejection rates are the most often-cited benefits from technology adoption. 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. Flexible manufacturing systems (FMS), use of robots and automated materials handling systems reduce set-up times and other interruptions so that products flow more smoothly and faster through the plant. Integrated production control systems, such as manufacturing resource planning (MRP II) and enterprise resource planning systems (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.

Data has been collected to study and analyze the status of new/advanced manufacturing technology (AMT) adoption by the organizations. It includes Computer aided manufacturing (CAM), Computer aided design (CAD), Computer aided engineering (CAE), Robotics and Group technology, Computerized numerical control machines (CNC), Flexible manufacturing system (FMS), Soft technologies (MRP, MRPII and JIT etc), Automatic material handling systems, enterprise resource planning systems (ERP) and many other forms of factory automation and control, that can provide cost efficient flexibility and flow in manufacturing.

Table 4.5 Level of new technology adoption

S. No.	Level of new technology adoption	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Computer aided manufacturing (CAM)	10	9	12	20	9	189	63.00
ii.	Computer aided design (CAD)	1	14	15	19	11	205	68.33
iii.	Computer aided engineering (CAE)	5	15	15	13	12	192	64.00

iv.	Use of Robotics	21	14	13	9	3	139	46.33
v.	Computerized numerical control machines (CNC's)	5	9	12	20	14	209	69.67
vi.	Flexible manufacturing system (FMS)	10	15	16	14	5	169	56.33
vii.	Soft technologies (MRP, MRPII and JIT etc)	6	15	19	13	7	180	60.00
viii.	Automatic material handling systems	12	7	24	11	6	172	57.33
ix.	Administrative approaches (ERP, OA)	6	8	18	19	9	197	65.67

The Table 4.5 depicts the mixed response for the level of adoption of new technology by the manufacturing organizations. The highest contribution to overall score of new technology adoption is by the use of computer-aided technologies including CAD/CAM/ CAE/CNC with an average score of 64.25%. Secondly, the use of integrated production control systems including ERP and soft technologies have an average score of 62.84%. FMS/use of Robotics and automated material handling systems jointly has attained the average score of 53.33%. However, it has been interestingly observed that about 34% of the organizations are not using robotics and group technology at all. The overall score of 61.18% gives an idea about the moderate extent for adopting new technology by the manufacturing organizations.

4.5.1 Need for New Technology Adoption

Organizations are adopting new technology for variety of reasons leading to creating an environment in which they have a competitive edge based on its use of AMTs. It includes improved flexibility in production system, fostering of next generation technology, reducing the dependency on external suppliers, increased productivity and quality. The survey indicates the level of importance for these factors and presented in the Table 4.6.

Table 4.6 Need for new technology adoption

S. No.	Need for new technology adoption	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	To improve flexibility in the manufacturing system	0	3	23	24	10	221	73.67
ii.	To reduce the dependency on external suppliers	4	16	23	10	7	180	60.00
iii.	Development / fostering of next generation technology	0	5	25	24	6	211	70.33
iv.	To improve productivity	0	2	6	32	20	250	83.33
v.	To improve product quality	1	0	4	28	27	260	86.67

The need to improve the product quality and the productivity has remained the main rationale for adopting the new technology. Apart from these, it has been observed that the organizations are ardent to improve the flexibility in the manufacturing system and foster the next generation technologies at their places to achieve the excellence in business competitiveness. To reduce the dependency on external suppliers as a reason to adopt new technology achieve the least score that can be indicative of the fact that organizations might be developing a win–win relationship with the suppliers and fully exploiting their technological excellence in manufacturing and design.

4.5.2 Barriers to New Technology Adoption

Adoption of new technology has always been associated with the expectation of realizing certain benefits. However the high cost of adopting new technology, lack of top management support, absence of a written formal manufacturing strategy/ information on new technology, and customers' non receptiveness to new products can restrict the organizations to adopt new technologies. The manufacturing strategies form a critical link not only in an organization ability to adopt new technologies but also in their ability to knowingly shape their futures.

Table 4.7 Barriers for adoption of new technology

S. No.	**Barriers for adopting new technology**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	High cost of new technology acquisition	2	5	11	32	10	223	74.33
ii.	Lack of information on new technology and markets	8	21	17	12	2	159	53.00
iii.	Lack of customer responsiveness to new products	11	19	16	10	4	157	52.33
iv.	Non-existence of a written formal manufacturing strategy to help in new technology adoption.	5	11	16	18	10	197	65.67
v.	Top management unwillingness for short term risks	12	7	24	11	6	172	57.33

Table 4.7 presents the level of agreement by the organizations to the different parameters, as the barriers to adopt new technologies. High cost of new technology acquisition has been found to be the main barrier for adopting new technology, and followed by lack of existence of any written formal manufacturing strategy that helps in new technology adoption process. Unwillingness of the top management for taking short term risks, since new technology adoption decision may result in a lot of disruptions & risks in short term has been felt as a significant barrier in 50% of the organizations. Lastly, the 'lack of information on new technology' and markets and 'customer non-responsiveness to new products' has little to moderate effect in adopting the new technology.

4.6 Status of Sourcing Practices

There is a growing recognition of the contribution of sourcing practices (involvement of supplier base at various levels in an organization) to the attainment of manufacturing flexibility capabilities as a key competitive priority. Sourcing practices clearly has the potential to influence an organization's flexibility in responding to market demands. Sourcing practices range from mere purchase of standardized parts to the involvement of the suppliers in product design and development has proved to be a relevant strategic option for organizations narrowing their operations to focus on core competencies. Practices that an organization would consider important are those that integrate with its competitive priorities. In contrast to routine purchasing activities such as order taking and expediting, such integrated sourcing practices direct resources and emphasis on those activities that support and enhance competitive advantage. Data has been gathered for analyzing the role of sourcing practices in managing various competitive priorities for an organization, supplier involvement in managing market fluctuations, supplier selection criteria, buyer-supplier management orientation and flexibility of supplier in managing market fluctuations.

4.6.1 Need for Adopting Sourcing Practices

The importance of various factors that necessitated the organizations to adopt sourcing practices has been depicted in the Table 4.8.

Table 4.8 Factors for adopting sourcing practices

S. No.	Factors for adopting sourcing practices	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Adaptability to customer needs and requirement	2	1	16	24	17	233	77.67
ii.	Speed of capacity changeover in manufacturing system	0	3	19	32	6	221	73.67
iii.	Organization can focus on core activities like newly designed innovative products	2	1	11	31	15	236	78.67
iv.	Improvement in delivery of product variety	2	2	15	32	9	224	74.67
v.	Easy access to new technology and low delivery time	0	4	19	27	10	223	74.33
vi.	Reduce operating cost and risk of business	0	3	6	30	21	249	83.00

'Reduction in operating cost' and 'risk of business' has been considered as the most important factor to adopt the sourcing practices followed by the 'organizations orientation to focus on core activities' like newly designed innovative products. Further, the ‘adaptability to customer’s need and requirement’ has been found to be important with a total score of 77.67%. Lastly, the ‘improvement in delivery of product variety’, ‘easy access to new technology and low delivery time’ and ‘speed of capacity changeover in manufacturing system’ has scored comparatively low but significantly important score.

4.6.2 Level of Sourcing Practices

Although outsourcing is playing a predominant role in today’s business environment, companies obviously have alternative sourcing practices to consider. These sourcing practices are largely determined by the companies’ position in the supply chain and sectoral pattern, and they all influence corporate identity. These are make-or-buy the standardized parts, outsourcing and strategic sourcing. As one would expect, we found that 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. 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. 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. Strategic sourcing is defined as the process of planning, implementing, controlling, and evaluating highly important purchasing in an effort to meet an organization’s goals. The 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. The level of supplier involvement in managing market fluctuations has been studied in the survey and presented in the Table 4.9.

Table 4.9 Level of supplier involvement

S. No.	**Level of supplier involvement**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	Purchase of standardized parts from suppliers	0	7	18	26	9	217	72.33
ii.	Involvement of supplier(s) in manufacturing	7	12	21	13	7	181	60.33
iii.	Involvement of supplier(s) in design and new product development process (strategic sourcing)	6	13	22	10	9	183	61.00

Firstly, it has been observed that the organizations are using the supplier base for the supply of standardized and commodities items with the highest total score depicting cost-based decision to purchase commodity items from suppliers. However, the outsourcing of manufacturing facilities as non-strategic sub-systems and involvement of supplier(s) in design and new product development process as strategic sub-systems has also achieved the equaled and significant score.

4.6.3 Supplier Selection and Assessment

In response to escalating competition, shorter product life cycles, and rapidly changing customer demands, organizations have been more concerned with appraising and developing supplier capabilities. This increases the importance of effective supplier selection and assessment. Supplier selection and assessment 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. An organization'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. Competitive factors that have been considered in the study for setting up the supplier selection and assessment criteria includes suppliers' flexibility, financial status, technological competence, consistency for quality and delivery, level of relationship and suppliers' competitiveness. The sub-factors have further been delineated in the survey to exhaustively analyze the relation between sourcing and supplier selection. The importance of these factors for the sample organizations has been depicted in the Table 4.10.

Table 4.10 Supplier assessment and selection

S.No.	**Importance of competitive factors for setting supplier selection criteria**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	Financial conditions of the supplier	0	2	14	32	12	234	78.00
ii.	Profitability of supplier	1	3	21	28	7	217	72.33
iii.	Supplier responsiveness to demand fluctuations *(volume changes, capacity etc.)*	0	0	10	26	24	254	84.67
iv.	Supplier modification capabilities	0	1	8	31	20	250	83.33
v.	Supplier integration in design	0	5	25	18	12	217	72.33
vi.	Design and innovative capabilities of supplier	1	1	20	26	12	227	75.67
vii.	Technological competence	0	0	8	38	14	246	82.00
viii.	Conformance to quality	0	0	5	14	41	276	92.00
ix.	Consistent delivery and short delivery time	0	0	6	15	39	273	91.00
x.	Length of relationship	0	1	10	32	17	245	81.67
xi.	Competitive scope of supplier	0	1	8	27	24	254	84.67

Amongst the various factors, 'the importance of quality conformance', 'consistent delivery' and 'short delivery time' by the supplier has been found to be of highest with a average score of 91.5%. Secondly, the 'level of supplier responsiveness' to demand fluctuations (product volume, variety and innovations) has facilitated the organizations to assess their capabilities and selection. Flexibility dimensions including the 'supplier responsiveness to demand fluctuations' and 'supplier modification capabilities' have also significantly influenced the supplier selection process. However, the 'supplier integration in design' at strategic level has moderately impacted the selection process, indicative of the fact that organizations are allocating more resources to their core competencies and encouraging the outsourcing of non-core manufacturing activities. Furthermore, the 'supplier competitive scope', 'technological competence' and 'the level of relationship' have positively influenced the supplier selection process. Organizations have given a relatively less but moderate importance to the financial status and profitability aspect of the supplier with a average score of 76.17%.

4.6.4 Buyer – Supplier Management Orientation

A close relationship with supplier has always been of key importance in an industrial scenario. A close relationship means that channel participants share the risks and rewards and have willingness to maintain the relationship over the long term. Moreover, through a well-developed long-term relationship, a supplier becomes part of a well-managed supply chain and ''it will have a lasting effect on the competitiveness of the entire supply chain''. It has been found in the Table 4.11 that organization strive to establish long term strategically managed relationship with key suppliers which in turn have a positive impact on the organization performance. However, it has been established in the survey that supplier's integration in manufacturing system will have low to moderate impact on an organization performance in terms of loss of control, confidentiality dependency and which in course, lead to organizational complicacies.

Table 4.11 Buyer – supplier management orientation

S.No.	Level of buyer–supplier management orientation	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Our organization strive to establish long term relationship with suppliers	0	0	4	23	33	269	89.67
ii.	Organization rely on small but high quality suppliers	0	2	13	25	20	243	81.00
iii.	Suppliers integration leads to complicacies, loss of control and confidentiality dependency	4	9	22	21	4	192	64.00

4.7 Status 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. Understanding the constituent dimensions of manufacturing flexibility and their interrelationships would be of value to the firms whose competitive strength depends on flexible manufacturing. However, the development of a generic taxonomy is likely to remain elusive as manufacturing flexibility clearly possesses a long term (strategic), midterm (tactical) and short term (operational) flexibility dimension; it can manifest itself in many forms at various and distinct operational levels in an organization. These dimensions 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. The categorization of various dimensions include machine flexibility, material-handling flexibility, routing flexibility, programme flexibility, process flexibility, mix flexibility, volume flexibility, modification flexibility, production flexibility, delivery flexibility, and demand flexibility. The status of manufacturing flexibility at different levels and for different dimensions has been studied and presented in Table 4.12.

Table 4.12 Level of manufacturing flexibility

S.No.	Level of Manufacturing Flexibility	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	The manufacturing system can quickly changeover to a different product mix	1	3	15	25	16	232	77.33
ii.	A large number of product categories are produced in the manufacturing system	0	4	5	35	16	243	81.00
iii.	Volume changes can be handled easily	0	10	7	29	14	227	75.67
iv.	Process improvements can be introduced in the manufacturing system	0	0	5	28	27	262	87.33
v.	The manufacturing system can be expanded easily when needed in the long run	0	3	11	31	15	238	79.33
vi.	Manufacturing system expansions do not affect the quality levels of output	0	3	13	28	16	237	79.00
vii.	The manufacturing system can handle many different delivery sequences	0	8	7	31	14	231	77.00
viii.	The product configuration can be changed many times during the	0	9	15	25	11	218	72.67

	manufacturing process to accommodate customer preferences							
ix.	The performance of the manufacturing system is not affected by a change in product design	3	18	11	17	11	195	65.00
x.	The manufacturing system can put the new product design into production quickly	0	12	15	25	8	209	69.67
xi.	Employees can perform many different types of tasks	0	6	12	24	18	234	78.00

The total percentage score for the different dimensions of manufacturing flexibility ranges from 65.0 - 87.33 leading to the connotation that organizations have moderate to high capability to handle the internal and external fluctuations in the manufacturing system. Amongst the various dimensions the organizations have an utmost agreement that they can introduce the process improvements in the manufacturing system, followed by their ability to produce large number of product categories, leading to the achievement of manufacturing flexibility at the medium/tactical level including process flexibility. Secondly, the organizations are of the view that the manufacturing system can be expanded easily when needed in the long run and expansions do not affect the quality levels of output for the achievement of expansion flexibility. Further, the organizations have agreed to the fact that their employees can perform many different types of tasks and thus high level of manpower/labor flexibility. After that, the organizations concurred to their capacity to handle volume changes, changeover to different product mix and handling the different delivery sequences quickly and efficiently with a total percentage score of 75.6, 77.3 and 77.0 respectively. However, the manufacturing flexibility at strategic level including delivery and market flexibility has found to be the area of concern for the organizations. The organizations moderately agree to the fact that the product configuration can be changed many times during the manufacturing process to accommodate customer preferences and manufacturing system can put new product design into production quickly. Lastly, the organizations are of the view that the performance of the manufacturing system is affected by the change in product design.

The overall status of manufacturing flexibility for the responding organizations has been depicted in the figure 4.7. Based on this score in all the 60 organizations, the average value (μ) and standard deviation (σ) has been calculated. This score is plotted on a dot chart with organizations on X-axis and score on Y-axis. The dot chart is shown in figure 4.7. The centre line corresponds to the average score (μ) of all the organizations, upper line indicates the value μ + σ and the lower line indicates the value μ - σ. With the help of μ and σ, the performance of organization has been rated as follows:

Greater than (μ+σ)	:	V. Good
Between μ and (μ+σ)	:	Good
Between (μ-σ) and μ	:	Fair
Below (μ-σ)	:	Poor

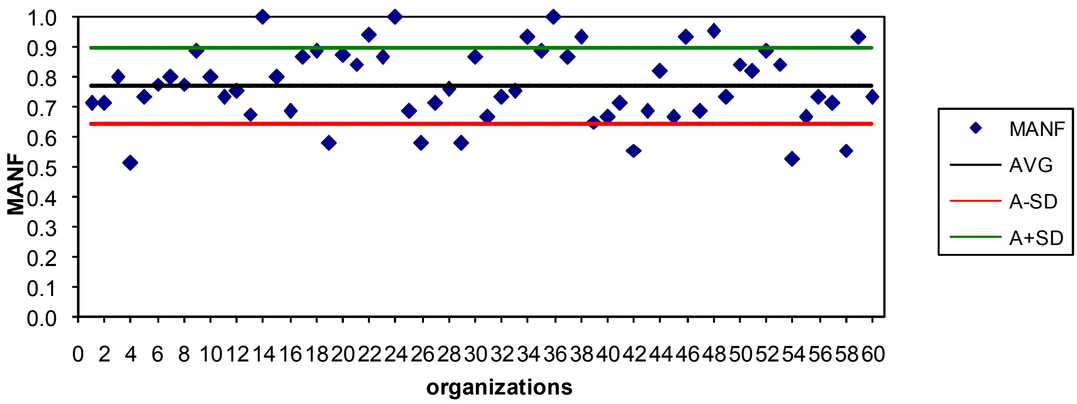


Figure 4.7 Status of manufacturing flexibility

The current status of manufacturing flexibility for the respondent organizations is very good with an average score of 0.76 and standard deviation of 0.11 only. The figure 4.7 indicates that the status of manufacturing flexibility. In 15% of the organizations, it is very good, which indicates the capability of the organizations to achieve the manufacturing flexibility at operational, tactical and strategic level. Further, 34% organizations attain a good status and have a score between 0.77 to 0.89.These organizations moderately agree to achieve the various dimensions of manufacturing flexibility at operational and tactical level, but have comparatively low score at strategic level. In 40% organizations, the status of manufacturing flexibility is fair. These organizations need to strengthen their manufacturing capabilities at all levels for effectively and efficiently achieve the flexibility aspect. For the remaining 11% organizations, the status of manufacturing flexibility is in poor state. These organizations are weak and ill prepared and a major improvement plan is urgently needed at all levels for achieving different manufacturing flexibilities.

4.7.1 Organizational Competence

The manufacturing performance in turn leading to the competitive success of an organization is based on its responsiveness to manage the market fluctuations efficiently and effectively and examined in the dimensions of cost, quality, delivery, customization responsiveness and new product introduction time performance.

Table 4.13 Level of organizational competence

S. No.	Level of Organizational Competence	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Improved processes and quality	0	0	8	33	19	251	83.67
ii.	Responsiveness to customers demand	0	0	10	30	20	250	83.33
iii.	To adapt itself or its organizational structure to changes in business environment	0	7	14	19	20	232	77.33
iv.	Rapid delivery of innovativeness in design of products	1	5	22	23	9	214	71.33
v.	To operate efficiently at different levels of output	0	0	18	32	10	232	77.33

Table 4.13 shows the level of organizational competence for various flexibility oriented tasks and among the foremost is the ‘responsiveness of the organizations to the customer’s demand’ and followed by ‘providing improved processes and quality’. Further, organizations adapt itself or its structure to the changes in business environment and operate efficiently at different levels of output. However, the deliverance of innovativeness in design of products achieves the least but significant score with in the organizational competencies.

4.8 Impact of Adopting New Technology vis-à-vis Sourcing Practices

Manufacturing capability of an organization depends upon its ability to handle the market fluctuations competently in dynamic environment. AMT/New technology may be used to alter the rules of competition in industries, in effect creating an environment in which the organization has a competitive edge based on its use of AMTs. However, making the right technology choices and successfully integrating the new technology into the environment are significant challenges for many organizations. Maintaining sufficient expertise in all areas to keep abreast of technology changes, and having the resources to allow them to evaluate all the potential technologies is a cost burden fewer and fewer organizations can bear. Keeping into these facts in mind, scholars and practitioners have also supported the role sourcing practices as an efficient way to address organizational competitiveness.

The level of change in the manufacturing capabilities i.e. product quality, flexibility, cost, delivery, profit and effect on market share due to the adoption of sourcing practices and new technology for the organizations have been studied in depth and descriptively analyzed in this section.

4.8.1 Impact of Adopting New Technology

Table 4.14 depicts the level of change in the manufacturing capabilities of the organizations as a result of adopting new technology. Increase in product quality in terms of its performance and features have found to be the fundamental factor for augmenting the adopting of AMT with more than 84% of the respondent organizations have achieved moderately to significant improvement in the quality dimension. Delivery of customized product with reduced lead-time adds to the organizational competence and in courses its manufacturing flexibility. Total score of delivery aspect has found to be very encouraging as speed of delivery and number of customized product offered has significantly increased due the adoption of new technology. Further, the new product lead-time has remained unaltered or moderately increased having total score of 67.33% only. However, the study has been designed and executed with a focus to achieve the various dimensions including volume, modification and delivery aspect of manufacturing flexibility. Analysis of flexibility aspect has revealed that variety of modified products; delivery of innovative products and capacity to change product volume has moderately increased in 62% of the organizations and only 7% of the organizations achieved a significant improvement in the flexibility as a result of adopting new technology. Nevertheless, for 21% of the organizations the level of flexibility remained the same. Further, the analysis exposed the result of adopting new technology on the financial and market aspects of the organizations. The effect on the cost of the product has attained a mixed response; with 35% of the organizations having achieved the significant to moderate decrease and 46.7% with moderate to significant increase in the product cost as a result of adopting new technology. However the cost of the existing and future product innovations have shown an upward trend with moderate increase, that can be resulted due to the high cost of technology acquisition in short term. Afterward, the market share and net profit of the organizations have revealed a considerable improvement as a result of adopting AMTs/new technology with a total score of 76.67% and 71% respectively. Finally, the analysis has revealed a moderate to significant improvement in manufacturing capability of the organizations associated with large investment in new technology in the short term.

Table 4.14 Impact of adopting new technology

Impact of adopting new technology on performance objectives		Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
1. PRODUCT QUALITY								
i.	Performance of products	0	2	10	24	24	250	83.33
ii.	Features of products	0	1	6	34	19	251	83.67
2. DELIVERY								
i.	Speed of delivery	0	1	11	32	16	243	81.00
ii.	Number of customized product offered	0	2	12	28	18	242	80.67
iii.	New product lead time	4	14	11	18	13	202	67.33
3. FLEXIBILITY								
i.	Variety of modified products	0	4	13	34	9	228	76.00
ii.	Delivery of innovative products	0	2	15	38	5	226	75.33
iii.	Capacity to change product volume	0	3	11	39	7	230	76.67
4. COST								
i.	Product cost	5	16	12	23	4	185	63.67
ii.	Cost of future product innovations	1	18	13	22	6	194	64.67
5. EFFECT ON MARKET SHARE		0	3	11	39	7	230	76.67
6. NET PROFIT		0	7	14	38	1	213	71.00

4.8.2 Impact of Adopting Sourcing Practices

There is a growing recognition of the contribution of sourcing to the attainment of manufacturing capabilities. Table 4.15 depicts the level of change in the manufacturing capabilities of the organizations as a result of adopting sourcing practices. It is clear that sourcing has the potential to influence a organization's capability in responding to market demands. Firstly, among the various performance objectives, sourcing has significantly and positively influenced the outcome of the organizations in terms of added flexibility and delivery aspects. The capacity and capability of an organization to achieve the volume and modification flexibility has been significantly improved by the adoption of various sourcing practices with an individual score of 79.67% and 80.67%. Secondly, the speed of delivery and its reliability in general and for the deliverance of innovative products has seen a considerable upside movement with the adoption of sourcing practices. Further the quality in terms of process capabilities and conformance has seen a moderate to significant improvement with an average score of 77.7%. Further, the analysis exposed the result of adopting sourcing practices on the financial and market aspects of the organizations. The organizations image and goodwill have increased to a large extent (more than 10% in relative terms) with no organization has reported for the decrease in the same. Sourcing practices have positively impacted the market share and net profit of the organizations with an average moderate increase of about 10% in relative terms. The cost of the product remained the same on an average with the adoption of sourcing practices. In contrast with the adoption of new technology where the main achievement is the quality, sourcing practices have significantly improved the flexibility and delivery dimensions of the manufacturing capabilities.

Table 4.15 Impact of adopting sourcing practices

Impact of adopting sourcing practices on performance objectives		**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
1. PRODUCT QUALITY								
i.	Process capabilities	0	0	16	36	8	232	77.33
ii.	Quality conformance	0	2	11	38	9	234	78.00
2. DELIVERY								
i.	Delivery reliability	0	0	13	35	12	239	79.67
ii.	Speed of delivery	0	0	16	33	11	235	78.33
3. FLEXIBILITY								
i.	Variety of modified product	0	0	11	36	13	242	80.67
ii.	Delivery of innovative products	0	0	22	33	5	223	74.33
iii.	Capacity to change product volume	0	3	7	38	12	239	79.67
4. PRODUCT COST		2	15	17	22	4	191	56.33
5. EFFECT ON MARKET SHARE		0	3	14	38	5	225	75.00
6. NET PROFIT		1	6	12	35	6	219	73.00
7. ORGANIZATION IMAGE AND GOODWILL		0	0	9	36	15	246	82.00

4.8.3 Relative Impact of Adopting New Technology vis-à-vis Sourcing Practices

The descriptive analysis of the data has revealed the certain outcome and shown in figure 4.8. Sourcing practices has an edge over the new technology for achieving the ‘capacity to change product volume’ and ‘variety of modified products’ with an individual score of 79.7% and 80.7% in relation with 76.7% and 76% for new technology. However for achieving the ‘delivery of innovative products’, both practices have equal importance with new technology possessing hairline edge of 1.1% over sourcing practices.

Organizations have always given a key importance to assess the relative impact of new technology vis-à-vis sourcing practices on their manufacturing capabilities. Various performance objectives of strategic importance include quality, flexibility, delivery, cost, market share and net profit, accomplishment of which in turn increases the competence of organization in the market. Figure 4.9 revealed the fact the sourcing practices are leading in flexibility, delivery and net profit aspects in contrast to new technology, which leads moderately for quality and market share.

However a very thin line is drawn when both the practices confront on the cost factor leading to the connotation that though both the practices are significant and important, the sourcing practices will lead to the inducement of manufacturing flexibility more effectively and competitively and focus of technology will be on quality aspect leading to the attainment of core competencies.

Although, the focus is to assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

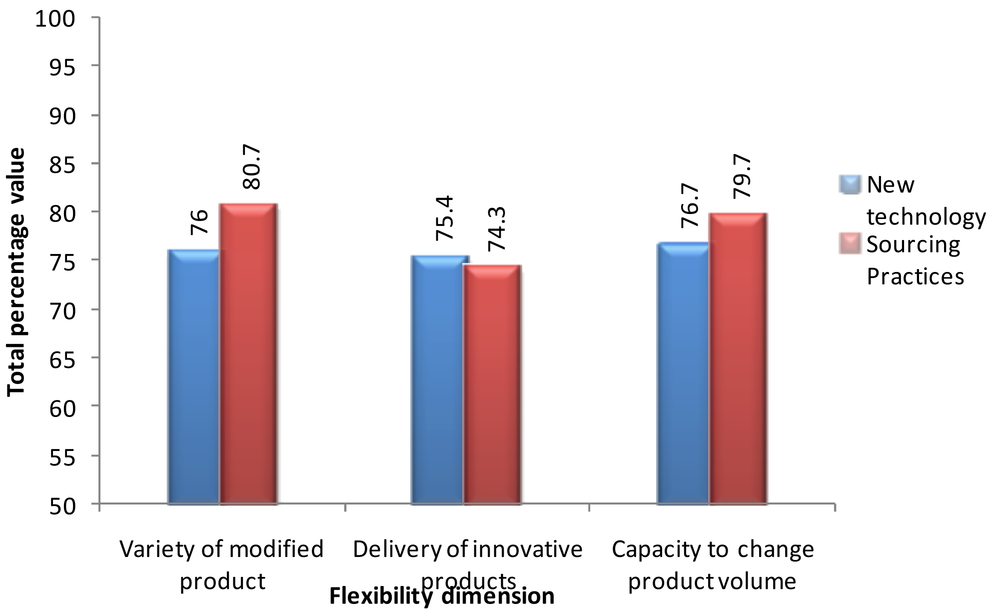


__Figure 4.8 Impact of new technology vis-à-vis sourcing practices on different flexibility item measures__

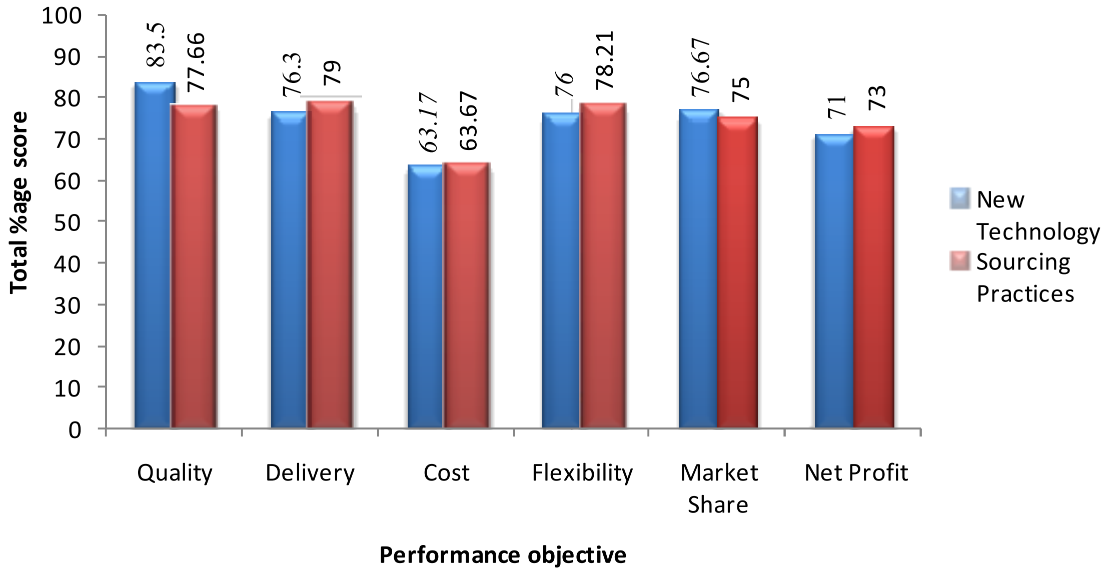


Figure 4.9 Impact of new technology in comparison with sourcing practices on business performance

The impact of new technology in comparison with outsourcing and strategic sourcing on the volume, modification and delivery flexibility has been analyzed and presented in the figure 4.10. It has been found that role of advanced manufacturing technology and outsourcing (OS) the sub strategic manufacturing activities has mostly persuaded the achievement of volume flexibility, followed by the moderate impact of strategic sourcing (SS).

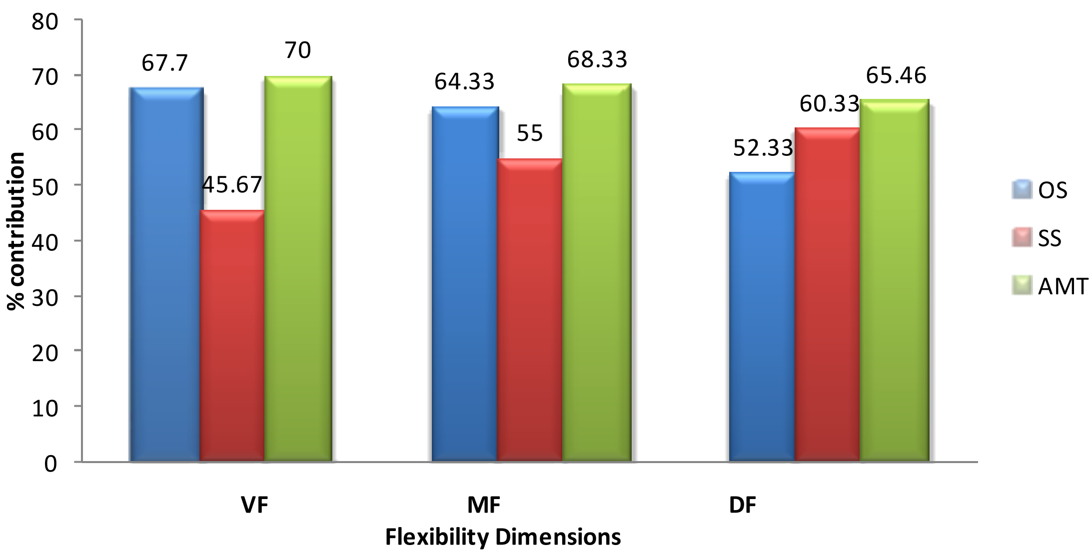


Figure 4.10 Impact of new technology in relation to sourcing practices on different flexibilities

In case of modification flexibility, the role of strategic sourcing in terms of percentage contribution has significantly increased as compared to its contribution to the volume flexibility, however in absolute terms the role of AMT and OS remained on the higher side. For delivery flexibility, the role of strategic sourcing has been found to be further elevated, although at the role of AMT has a substantial impact on its achievement. The finer niceties of the results have been discussed in the empirical examination in the Section 4.9.

Further, the overall performance of new technology and supplier based sourcing practices in managing manufacturing flexibilities has been studied, analyzed and presented in figure 4.11. Descriptively, it has been found that the 21.6% of the organizations are of the view that sourcing and AMT are highly significant in achieving the different manufacturing flexibilities. 66.6% of the organization is of the view that AMT are moderately significant in achieving the manufacturing flexibility in contrast to 58.4% in favor of sourcing practices in this category. However, 20% organizations feels sourcing indifferent as compared to 11.7% admits the least priority for the AMT.

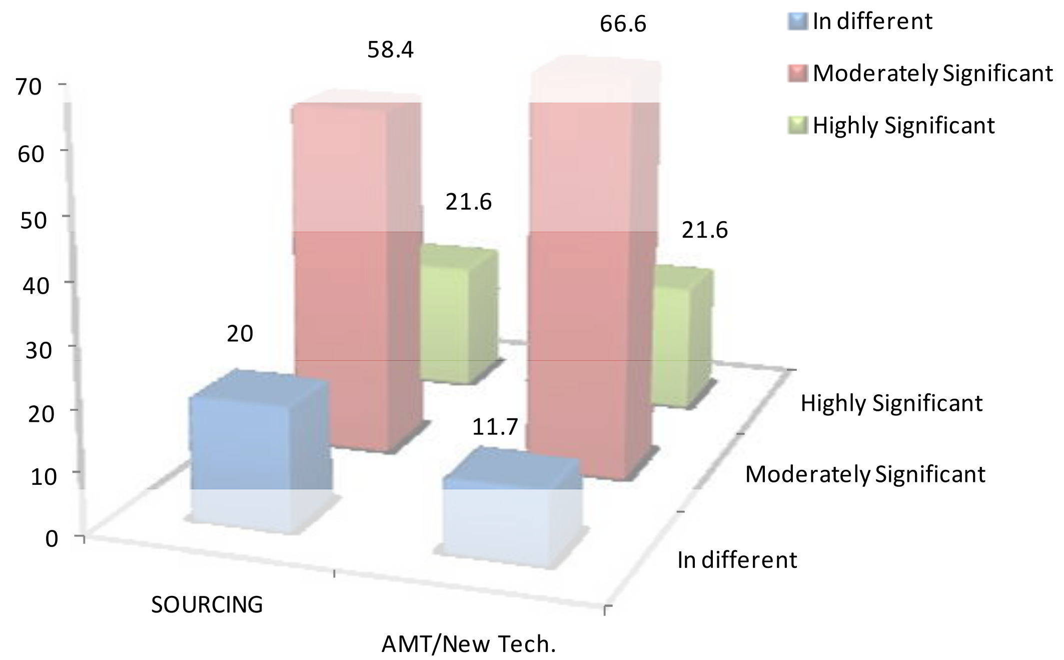


Figure 4.11 Overall performance of new technology and supplier based sourcing practices in managing manufacturing flexibilities

4.9 Empirical Examination of Relation between Flexibility, Technology and Sourcing

This section aims to report the findings of an exploratory study administered in north Indian medium and large scale manufacturing organizations with the help of empirical examination. The study includes the manufacturing organizations that are in the process of achieving the manufacturing flexibilities at all or various levels by acquiring, developing or utilizing the advanced manufacturing technology or by the use of specific/different sourcing practices. The statistical results will further suggests the relationships between sourcing practices, advanced manufacturing technology and manufacturing flexibilities at different levels of manufacturing flexibility. Finally, the analysis will explore the relation between specific sourcing practices or advanced manufacturing technology to target specific manufacturing flexibility in pursuit of agility-based competitive advantages.

Manufacturing flexibilities improves an organization capability to respond to customer demands without incurring excessive time and cost penalties. The purpose of this research is to explore and examine the relative impact of sourcing practices and new technology at different levels of manufacturing flexibilities and primarily focused on delivery, modification and volume flexibility as sourcing will mostly influence these dimensions. Scale items have been used in the analysis, since the research interest is to examine the effects of independent variables on dependent variables as discussed in next section. This approach is consistent with previous research studies, which employ single scale items for various variables (Ettlie and Penner-Hahn 1994, Suarez *et al.* 1996, Gupta and Somers 1996). Item measures for volume flexibility; modification flexibility and delivery flexibility have been mostly adapted from existing scales (Sethi and Sethi, 1990; Upton, 1995; Gerwin, 1993; Gupta and Somers, 1992; Koste and Malhotra, 1999; D'Souza and Williams, 2000). The Gupta and Somers (1996) scale consists of a 21-item instrument, using 5-point Likert-type measures, developed from data from 269 organizations. Existing literature has been also consulted to develop item measures for the advanced manufacturing technologies, encompassing utilization of cellular manufacturing, group technology, CAD/CAM, FMS and JIT production systems etc. (Ward *et al.*, 1994; Snell and Dean, 1992; Tranfield *et al.*, 1991) and sourcing practices, encompassing involvement of supplier base at different levels (Suarez *et al.* 1996, Narasimhan and Das, 2000; Narasimhan and Das, 2004). Scale items relating to manufacturing flexibilities categorized as *dependent variables* and sourcing practices and AMT categorized as *independent variables* have been used in the analysis. Individual item measures have been developed posited to impact manufacturing flexibility in the study. A 1–5 Likert-type scale has been employed for all item measures in the questionnaire. Inter-item analysis is used to check the scales for internal consistency or reliability. Cronbach's alpha is calculated and tested for each scale, as recommended for empirical research in operations management (Flynn *et al.*, 1990; Malhotra and Grover, 1998). The convergent and discriminate validity of the constructs and their measures have been done and various statistical tools and techniques including correlation analysis, canonical correlation and multiple linear regressions have been employed to predict the results.

4.10 Development of Measurement Constructs for Independent Variables - Advanced Manufacturing Technologies (AMTs)

The theory and categorization of advanced manufacturing technologies have been explored and examined with insights from the existing literature in this section. The measurement constructs have been developed and further used in the empirical analyses.

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. Advanced manufacturing technology appeared to represent a perfect marriage between technological potential and the manufacturing challenges (Dangayach and Deshmukh, 2001). 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), 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).

Past research has described advanced manufacturing technology as a multi-dimensional construct that includes the use of 'hard' machine related aspects: robotics, CNC hardware, CAD/CAM, etc.; and 'soft' reduction techniques, JIT, etc. (Burgess and Gules, 1998;

Clark, 1996; Dean and Snell, 1996; Roth and Griffi, 1995; McCutcheon *et al.*, 1994; Tranfield *et al.*, 1991). The construct definitions provided by Tranfield *et al.* (1991) and Boyer *et al.* (1996) were of interest to this research because of their breadth of scope, transcending automated machine typology to enfold CAD/CAM, information technology, configurational processes, use of JIT/Kanban, and administrative processes in their description of an advanced manufacturing system. Boyer *et al.* (1996) empirically derived three separate dimensions of AMT: design, manufacturing and administrative. Design included a mix of design and process technologies such as CAD, CAE, CAM, computer-aided process planning, and the use of CNC equipment. Manufacturing covered technology elements such as FMS, real time process control systems and robotics, while the administrative dimension included MRPII, EDI, and knowledge and decision support systems. Swamidass and Kotha's (1998) dimensionalization of the AMT construct was not very different from Boyer *et al.* (1996) classification. They (the former) developed four dimensions: information exchange and planning technologies (MRPII, EDI, etc.), and production design technology (CAD/CAE), and distinguished between high-volume automation technology (robotics, manufacturing automation, computer-aided inspection, etc.) and low-volume automation technology (CNC, CAD/CAM, FMS). 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 and results show consistent tardy delivery performance, reinforcing that there is a shortage of guidance and knowledge on how to tackle uncertainty in SMEs in UK. Mora-Monge *et al.* (2007) investigated the issue of strategic fit between Advanced Manufacturing Technologies (AMT) and its impact on performance in developing countries. They used survey data collected from 125 manufacturing firms to develop his framework. 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.

A careful examination of these conceptualizations reveals three clear AMT domains: a design domain that is concerned largely with design technologies, a manufacturing domain that involves mainly process related technologies, and an infrastructural domain that comprises information production planning and control technologies. One key aspect of successful AMT systems that researchers have neglected to integrate under the rubric of advanced manufacturing technologies and practices is the human element. Ward *et al.* (1994) developed an infrastructural factor, involving worker training, empowerment, and job-enrichment.

Based on the above discussion and recognizing the inseparable role of human resource management practices in advanced manufacturing technology implementation (Snell and Dean, 1992; Narasimhan and Das, 2001), advanced manufacturing technology has been defined as the collective use of advanced manufacturing, design, infrastructural, and human resource management practices and systems in a manufacturing organizations. Specifically, the construct encompassed the following AMTs practices and their item measures.

- ***Technology investment in manufacturing systems (TMSYS):*** The use of advanced manufacturing systems-CNC machines, CAM, FMS, CIM, RO etc.
- ***Technology investment in manufacturing design (TDE):*** The use of computer aided design, engineering and testing.
- ***Technology investment in manufacturing infrastructure (TIMS):*** The use of infrastructural support systems-soft technologies to schedule production (MRP, MRPII, KANBAN/ JIT etc), administrative technologies (ERP, ABC, OA) and intermediate technologies (AMHS and AS/RS) usage in manufacturing.
- ***Investment in human resource management (THRM):*** The use of innovative human resource management practices and structures in manufacturing. However the role of human resource on achieving manufacturing flexibilities is not covered in the scope of this study.

Section T2 of the questionnaire contained questions to assess the present status of these factors. Descriptive statistics of these responses are given as Appendix B.

4.10.1 Technology Investment in Manufacturing Systems (TMSYS)

This construct includes a group of integrated hardware-based technologies which, when properly implemented, monitored and evaluated, can improve the operating efficiency and effectiveness of the adopting organizations in terms of its manufacturing capabilities. The item measures of the construct are primarily linked to the level of technology investment in manufacturing system with a prime motive to achieve the manufacturing flexibility and include:

i. Computer aided manufacturing (CAM)
ii. Robotics and Group technology (RO and GT)
iii. Computerized numerical control machines (CNC's)
iv. Flexible manufacturing system (FMS)

The responses to these item measures from the sample organizations have been summarized in the Table 4.16. Among the manufacturing technologies, the 'level of adoption of 'computerized numerical control machines' have been the foremost followed by 'investment in computer aided manufacturing system' and 'flexible manufacturing system'. The least score is with the use of robotics among the group.

Table 4.16 Technology investment in manufacturing systems

S. No.	Item measures for technology investment in manufacturing systems	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Computer aided manufacturing (CAM)	10	9	12	20	9	189	63.00
ii.	Use of Robotics	21	14	13	9	3	139	46.33
iii.	Computerized numerical control machines (CNC's)	5	9	12	20	14	209	69.67
iv.	Flexible manufacturing system (FMS)	10	15	16	14	5	169	56.33

These four factors have been averaged to indicate the level of use of technology in the manufacturing system for a particular organization. This has been graphically shown in figure 4.12 with the centre line representing the average value. It is observed that the score in technology investment in manufacturing system is in the range of moderate to large extent.

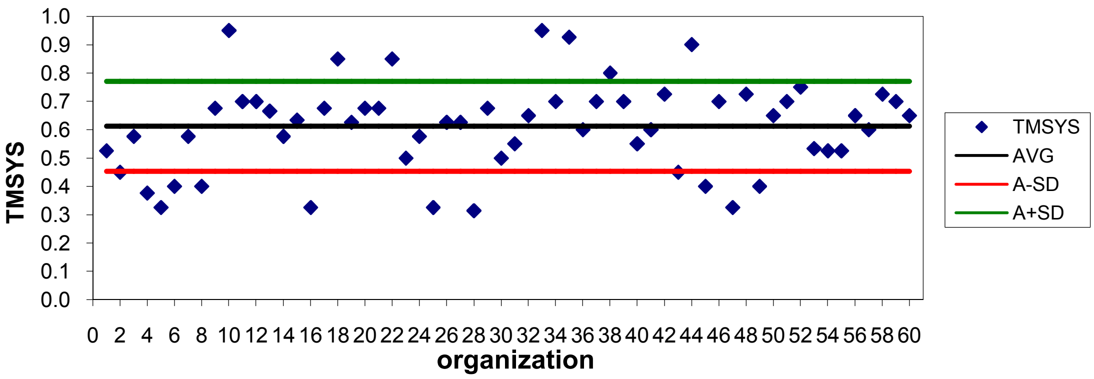


Figure 4.12 Role of technology investment in manufacturing system

The overall role of technology investment in manufacturing system is good with average score of 0.61 and standard deviation of 0.15 only. Among the sample of respondents, the status of technology investment in manufacturing system for 12% of the organizations is in very good range. For another 43% organizations it is in good range, 28% in fair and for remaining 17% the status is poor. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.67.

4.10.2 Technology Investment in Manufacturing Infrastructure (TIMS)

Technology used to schedule production, give administrative support to the organization and integrate its operations with the rest of the organization has been included in this construct. Integrated production control systems, such as manufacturing resource planning (MRP II) and enterprise resource planning systems (ERP), reduce inventories and raw materials, work-in progress and finished goods leading to the improvement of delivery and flexibility. Improvements in overall quality may be achieved through automated inspection and testing, better production, information and the more accurate delivery performances.

The item measures of the construct are largely associated with the amount of technology investment in manufacturing infrastructure and include the soft, intermediate and administrative technologies and listed as:

i. Soft technologies (MRP, MRPII, KANBAN/ JIT)
ii. Administrative technologies (ERP, OA)
iii. Intermediate technologies (AMHS, AS/RS)

The responses to these item measures from the sample organizations have been summarized in the Table 4.17.

Table 4.17 Technology investment in manufacturing infrastructure

S. No.	Item measures for technology investment in manufacturing infrastructure	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Soft technologies (MRP, MRPII and JIT etc)	6	15	19	13	7	180	60.00
ii.	Administrative technologies (ERP, OA)	6	8	18	19	9	197	65.67
iii.	Intermediate technologies (AMHS, AS/RS)	12	7	24	11	6	172	57.33

Analysis revealed that the role of technology investment in administrative approaches have been the foremost priority for the emerging organizations with the highest score among the group followed by importance of soft technologies to manage the integrated production control system. The automated material handling systems has scored the least score. The response to these three item measures has been averaged to assess the overall role of technology investment in manufacturing infrastructure. This has been graphically shown in figure 4.13.

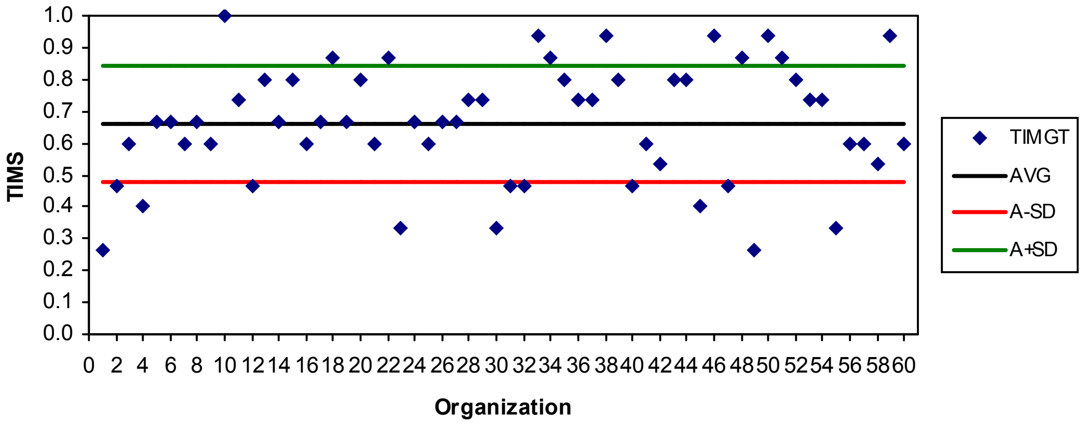


Figure 4.13 Role of technology investment in manufacturing infrastructure

The overall role of technology investment in manufacturing infrastructure is good with an average score of 0.67 and standard deviation of 0.18. Among the sample of respondents the status of technology investment in manufacturing infrastructure in 19% organizations is in very good range and for 40% organizations in good range, another 20% in fair and for remaining 21%, the status is poor. The figure depicts that 79% of the total sample companies have the score for this factor in range of fair to very good. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.857.

4.10.3 Technology Investment in Manufacturing Design (TDE)

This dimension of AMT includes computer-assisted drafting, design and engineering. The focus of AMTs is on the design of products and processes. The design lead times and delivery of innovative products can significantly be shortened with the use of technology investment in manufacturing design. The investment in this portal of technology will lead to the development of core competencies and hence market capabilities of the organizations. The item measures considered for this construct are:

i. Computer aided design (CAD)
ii. Computer aided engineering (CAE)/ Computer aided testing

Table 4.18 Technology investment in manufacturing design

S.No.	Item measures for technology investment in manufacturing design	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Computer aided design (CAD)	1	14	15	19	11	205	68.33
ii.	Computer aided engineering (CAE)	5	15	15	13	12	192	64.00

Table 4.18 shows the level of investment in the manufacturing design by the respondent organizations. It is pertinent that organizations are investing in design technology to a large extent with both the items scoring a relevant score. About 20% of the organizations believe that the investment in design technology is most important and they have invested in design technology to the full extent. The response to these two item measures has been averaged to assess the overall role of technology investment in design. This has been graphically shown in figure 4.14.

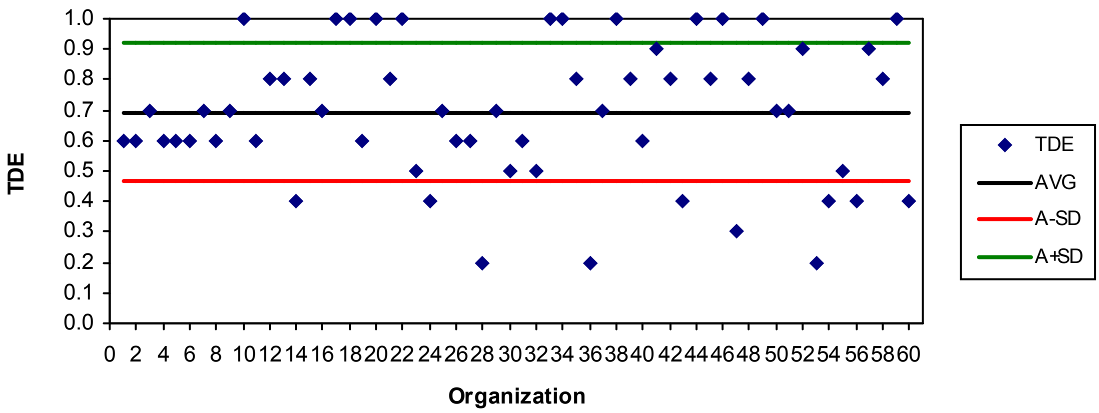


Figure 4.14 Role of technology investment in manufacturing design

The figure 4.14 shows that TDE has a good average of 0.7, but the standard deviation of 0.22 on one point scale is large enough to depict the high variability of the responses. However, 20% of the organizations have adopted the design technology to the full extent and are in a range of very good status followed by 37% in good range and above the average, another 27% in the fair and 16% as laggards and in the poor range below the lower limit. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.796.

4.11 Development of Measurement Constructs for Independent Variables - Sourcing Practices

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 the corporate competitive priorities. There is evidence that manufacturing organizations are increasingly obtaining volume, design and technology flexibilities through sourcing practices (Tully, 1994). Previous research has shown that purchasing of supplier capabilities can generate competitive advantages of time and cost (Handfield and Pannesi, 1995). Recent studies have found significant relationships between sourcing and different manufacturing flexibilities (Suarez *et al*. 1996, Narasimhan and Das, 2000; Narasimhan and Das, 2004). There is a growing recognition of the contribution of sourcing to the attainment of manufacturing flexibility capabilities. 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.

This study focuses on manufacturing flexibility as a key competitive priority. Distinct sourcing constructs related to sourcing practices, likely to influence the pursuing manufacturing flexibility objectives have been developed. This includes the 'supplier involvement in managing volume changes requests', 'supplier involvement in modifying products', 'supplier involvement in delivery changes request', 'supplier competencies' and 'supplier relationship'. Specifically, each of the construct encompassed the following item measures:

- ***Supplier involvement in managing volume changes request (SIVCR)***: Responsiveness to schedule volume changes, Speed of capacity changeover in manufacturing system, Supplier assistance in process improvement.
- ***Supplier involvement in modifying products (SIMP):*** Supplier assistance in minor product and process design changes, Supplier involvement in managing rapid change in product variety.
- ***Supplier involvement in delivery changes request (SIDCR):*** Supplier responsiveness to delivery changes requests and cross-functional teams with suppliers for product design and innovation.
- ***Supplier competencies (SCOMP):*** Supplier technological competence, Supplier flexibility in delivering the innovative products, Supplier financial

condition and profitability Supplier integration in design Competitive scope of the supplier and Supplier consistency.

- ***Supplier relationship (SREL):*** Length of relationship and level of cooperation.

Section S1-S5 of the questionnaire contained questions to assess the present status of these factors. Descriptive statistics of these responses are given as Appendix B.

4.11.1 Supplier Involvement in Managing Volume Changes Request (SIVCR)

The rationale of this construct is to establish a role of the supplier involvement in managing the non-core and operational competencies of the organization to meet the different manufacturing flexibility dimensions, directly or indirectly. The various factors considered in the construct with reference to the supplier involvement in managing volume changes request are:

i. Responsiveness to schedule volume changes and supplier flexibility
ii. Speed of capacity changeover in manufacturing system
iii. Supplier assistance in process improvement

Table 4.19 depicts the relative importance of all the item measures of the listed factors for the respondent organizations.

Table 4.19 Supplier involvement in managing volume changes request

S. No.	Item measures for supplier involvement in managing volume changes request	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Supplier assistance in managing process improvement	1	9	15	25	10	214	71.33
ii.	Supplier responsiveness to demand fluctuations (volume changes, capacity etc.)	0	1	8	31	20	250	83.33
iii.	Speed of capacity changeover in manufacturing system	0	3	19	32	6	221	73.66
iv.	Supplier flexibility in managing rapid change in product volume	0	5	18	33	4	221	73.66

The level of ‘supplier responsiveness to demand fluctuations (volume changes, capacity etc.)’ has achieved the highest score with more than 83% of the organizations have considered it to be highly important and followed by relatively significant and equal importance for supplier ‘speed of capacity changeover in manufacturing system’, ‘responsiveness to schedule volume changes’ and ‘supplier flexibility’. The response to these four item measures has been averaged to assess the overall role of supplier involvement in managing volume changes. This has been graphically shown in figure 4.15.

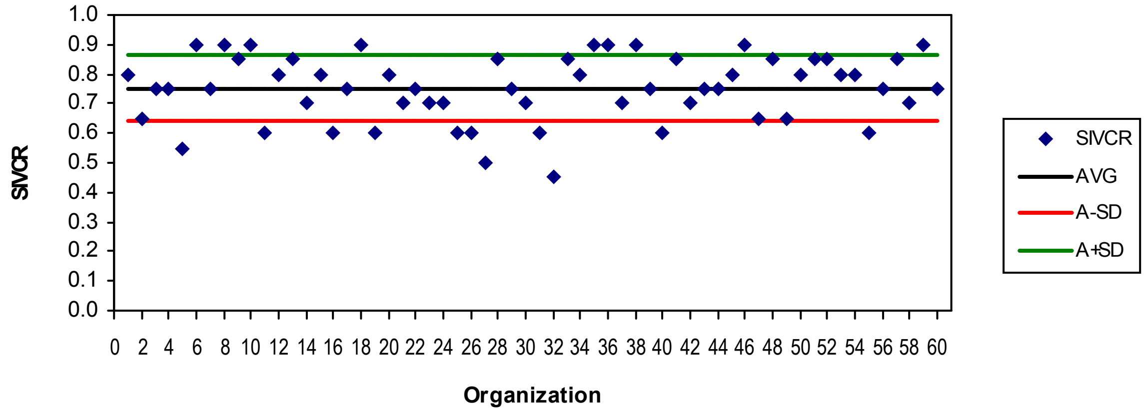


Figure 4.15 Role of supplier involvement in managing volume changes request

The figure 4.15 portrays that supplier involvement in managing volume changes has a very good average of 0.75 and standard deviation of 0.11 only. 15 % of the organizations are in a range of very good status followed by 47% in good range and above or on the average value, another 20% in the fair and 18% as laggards and in the poor range below the lower limit. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.839.

4.11.2 Supplier Involvement in Modifying Products (SIMP)

Involvement of supplier base in the manufacturing and design processes, which are phasing out as the key activities of an organization delivers the need to develop the supplier involvement in modifying existing products. The level of knowledge transfer capability and transfer competence of both buyer and suppliers in this category is high and suppliers are broadly classified as a capacity supplier. The purpose of SIMP for an organization remains the access to complementary competencies, rationalization of internal organization and multiple production creatia, e.g. lowered cost structure, shortened lead time and improved flexibility The various factors considered in the construct with reference to the supplier involvement in modifying products are:

i. Supplier involvement in managing rapid change in product variety
ii. Supplier flexibility in minor product and process design changes
iii. Supplier technological expertise in modifying products

Table 4.20 depicts the relative importance of all the item measures of the listed factors for the respondent organizations for analyzing the role of supplier in modifying products.

Table 4.20 Supplier involvement in modifying products

S. No.	Item measures for supplier involvement in modifying products	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Supplier involvement in managing rapid change in product variety	2	2	15	32	9	224	74.67
ii.	Supplier flexibility in minor product and process design changes	0	3	31	23	3	206	68.67
iii.	Supplier technological expertise in modifying products	0	1	8	31	20	250	83.33

Analysis revealed that the 'supplier technological expertise in modifying products' has been the most important factor for the organization with highest score and followed by role of 'supplier involvement in managing rapid change in product variety'. However, the 'supplier flexibility in minor product and process design changes' has attained the comparative low but significant score. The response to these three item measures has been averaged to assess the overall role of supplier involvement in modifying products. This has been graphically shown in figure 4.16.

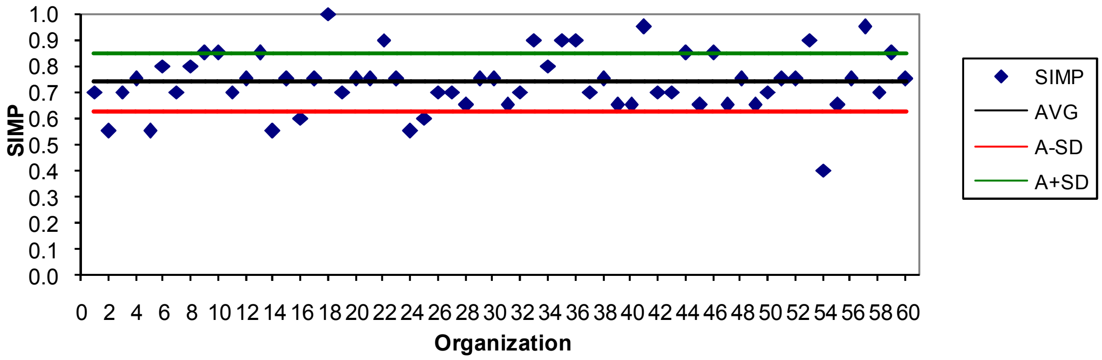


Figure 4.16 Role of supplier involvement in modifying products

The overall role of supplier involvement in modifying products is very good with an average score of 0.74 and standard deviation of 0.11 only. 23% of the organizations are in a range of very good status followed by 30% in good range and above or on the average value, another 35% in the fair range and 12% as laggards and in the poor range below the lower limit. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.835.

4.11.3 Supplier Involvement in Delivery Changes Request (SIDCR)

The level of capability and competence for the involvement of supplier in delivery changes request is exaggerated with joined manufacturing capability and crossed competence between the organization and the supplier. The level of knowledge dependence is very high and generation of synergy is witnessed among the buyer-supplier orientation. The various factors considered in the construct with reference to the supplier involvement in delivery request changes are:

i. Supplier responsiveness to delivery changes requests

ii. Cross-functional teams with suppliers for product design and innovation.

Table 4.21 depicts the relative importance of the item measure for the respondent organizations for analyzing the role of supplier involvement in delivery request changes.

Table 4.21 Supplier involvement in delivery changes request

S. No.	Item measures for supplier involvement in delivery changes request	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Supplier responsiveness to delivery changes requests (early supplier involvement in product design)	0	4	19	27	10	223	74.33
ii.	Cross-functional teams with external suppliers for innovation in product design	9	11	15	15	10	186	62.00

The above table shows that within the factors, the role of 'supplier responsiveness to delivery changes requests (early supplier involvement in product design)' is significant and of great importance to the organizations. The rationale might be the need to achieve the deliverance of flexibility and responsiveness to the market fluctuations. After that, the organization decision for 'cross-functional teams with external suppliers for innovation in product design' achieve moderate to significant importance in a phased and equated manner. The response to these factors has been averaged to assess the overall role of supplier involvement in delivery request changes. This has been graphically shown in figure 4.17 with the centre line representing the average value.

The overall role of supplier involvement in delivery request changes is good with an average score of 0.65 and standard deviation of 0.16. Among the sample of respondents, the status of supplier involvement in delivery request changes in 23% companies is in very good range and for another 23% companies in good range, 32% falls in fair range and for remaining 22% the status is poor. The figure depicts that 78.6% of the total sample companies have the score for this factor in range of fair to very good. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.769.

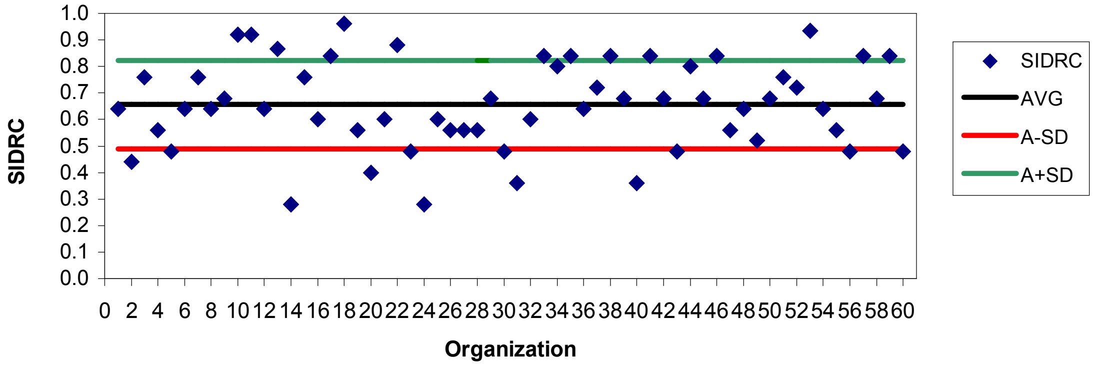


Figure 4.17 Role of supplier involvement in delivery request changes

4.11.4 Supplier Competencies (SCOMP)

The increasingly competitive markets are generally perceived to be demanding higher quality, flexibility and higher-performing products, in shorter and more predictable development cycle-times, and at lower cost. In practice, product development represents a complex challenge for many organizations today. They must contend with the deliverance of an increasing number of product and process technologies. Moreover, external sourcing of technology and technological knowledge (in the form of products and processes) from suppliers is increasing as a result of organizations focusing in their core competences and the need to be flexible to the changing and less predictable markets. In so far as representing a general trend, these factors expand the range of development options open to organizations and increase the importance of the role of suppliers in the product development process. Product development must therefore increasingly be managed as a concurrent, multi-disciplinary process. In terms of the manufacturing function and suppliers this is reflected in recommendations for the formal representation and active involvement of both manufacturing and suppliers on project teams, and a strategic approach to suppliers based on partnership sourcing arrangements and supplier development programme.

The various item measures drawn in the construct are related to the technological and manufacturing competencies of the supplier and classified as strategic supplier integration. It is the process of acquiring and sharing operational, technical and financial information and related knowledge with the supplier and vice versa. Strategic supplier integration is done in the organizations in order to better meet new product requirements and market fluctuations through developing and more effectively exploiting both the supplier's and organization's capabilities and cost structures. The construct includes the following measures that are:

i. Supplier consistency
ii. Supplier technological competence in design
iii. Supplier flexibility in delivering the innovative products
iv. Supplier financial condition and profitability
v. Competitive scope of the supplier

Table 4.22 depicts the relative importance of the item measures (from indifferent to most important) for the respondent organizations, for analyzing the importance of suppliers' competencies and involvement in product development process.

Table 4.22 Supplier competencies

S.No.	**Item measures for the level of importance for supplier competencies**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	Supplier technological competence in design	0	1	14	32	13	237	79.00
ii.	Supplier flexibility in delivering the innovative products	1	1	20	26	12	227	75.67
iii.	Supplier financial condition and profitability	1	3	17	30	9	223	74.33
iv.	Competitive scope of the supplier	0	1	8	27	24	254	84.67
v.	Supplier consistency (consistent delivery, shorts delivery time and quality conformance)	0	0	6	15	39	273	91.00

Within the item measures for 'supplier competencies', supplier consistency (consistent delivery, shorts delivery time and quality conformance) has the highest score of 91.0, and closely followed by 'competitive scope of the supplier' and 'supplier technological competence in design'. The least but significant scoring factors include 'supplier financial condition' and 'profitability and supplier flexibility' in delivering the innovative products.

The response to five item measures has been averaged to assess the overall role of supplier competencies in managing the flexibility. This has been graphically shown in figure 4.18.

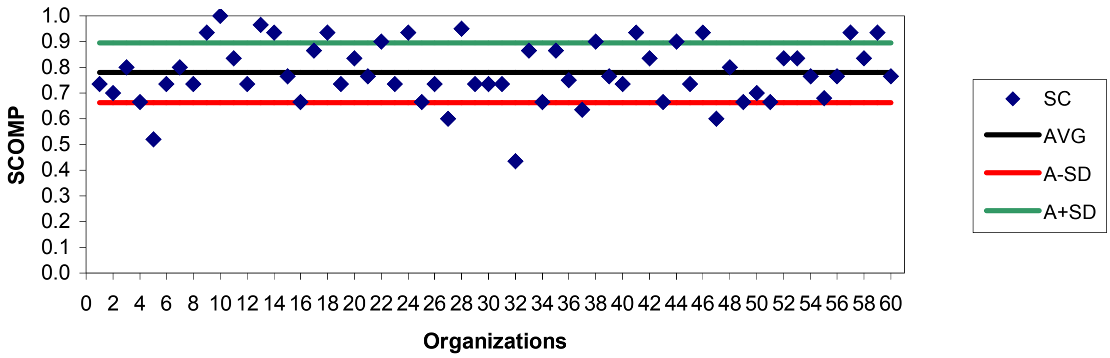


Figure 4.18 Role of supplier competencies

The overall role of supplier competencies is very good with an average score of 0.79 and standard deviation of 0.11 only. Analysis further revealed that 43.3% of the organizations are above the average value, out of which, 23.3% is in very good range and 20% of the organizations possess a good status. Further, 48.3% of the organization are in fair range and possess a moderately important score. Lastly, only 8.4% the organizations are in the poor range depicting the relatively reduced importance for the factor. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.805.

4.11.5 Supplier Relationship (SREL)

A close relationship means that channel participants share the risks and rewards and have willingness to maintain the relationship over the long term. Furthermore, through a well-developed long-term relationship, a supplier becomes part of a well-managed supply chain and will have a lasting effect on the competitiveness of the entire supply chain. Carr and Pearson (1999), investigate the impact of 'strategic purchasing' on 'buyer–supplier relationships' and the subsequent impact of 'buyer–supplier relationships' on the 'firm's financial performance'. They also found that strategically managed long-term relationships with key suppliers have a positive impact on the firm's financial performance. Organizations that do long-term planning and consider sourcing to be strategic are also likely to build long-term cooperative relationships with their key suppliers. The type of buyer–supplier relationship can vary from adversarial to cooperative. Adversarial buyer–supplier relationships are characterized by purchase transactions where the items are low in priority and there are numerous sources of supply. However, a cooperative buyer–supplier relationship is more desirable for the buying firm when purchased items are high in priority and the sources of supply are limited to a few suppliers. A cooperative relationship refers to the process of working together, over an extended period of time, for the benefit of both firms. The various factors considered in the construct with reference to the supplier relationship are:

i. Length of relationship

ii. Level of cooperation

The response to these item measures from the sample organizations has been summarized in the Table 4.23.

Table 4.23 Supplier relationship

S.No.	Item measures for supplier relationship	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	Length of relationship	0	1	10	32	17	245	81.67
ii.	Level of cooperation	0	1	8	27	24	254	84.67

The above table shows that for the variable, 'supplier relationship', the contribution of both of the item measures is significant with the 'level of cooperation' scoring higher than the 'length of relationship'. The response to item measures has been averaged to assess the overall role of supplier relationships in managing the dimensions of manufacturing flexibility. This has been graphically shown in figure 4.19.

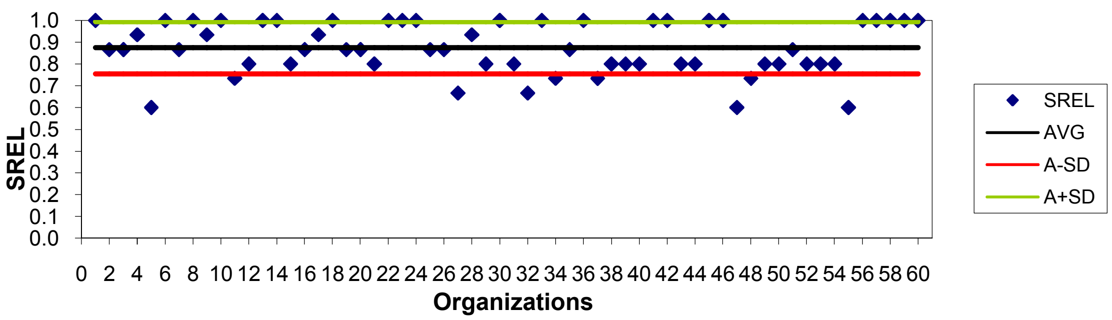


Figure 4.19 Role of supplier relationship

The overall role of supplier relationship is fabulous with an average score of 0.89 and standard deviation of 0.11 only. Among the sample of respondents, the very good status has been achieved by 37.3%, for 23.3% companies, it is in good range, 25% in fair and for remaining 14.4%, the status is poor. The figure depicts that there is a fixed trend for this factor, average is very high and the value of supplier relationship is crowded in narrow range. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.878.

4.12 Development of Measurement Constructs for Dependent Variables

The theory and categorization of different flexibilities have been explored and examined with insights from the existing literature. The measurement constructs concerning tactical and strategic level flexibilities i.e., volume, modification and delivery flexibility have been developed. The individual flexibility construct will depict its current status within the organization and will further explicate the nature of interaction between volume, modification and delivery flexibility and different methods of achieving it, mainly through adoption of advanced manufacturing technology or sourcing practices. As discussed earlier the flexibility constructs are considered as dependent variables in the empirical examination. This section will further explore the development and status of volume, modification and delivery flexibility in depth.

4.12.1 Volume Flexibility (VF)

The importance of volume flexibility has been widely discussed in the literature. Volume flexibility corresponds to the ability of manufacturing system to be operated profitable (in the short term) with various amount of volume for several products without incurring negative effects (e.g. time delays, changes in performance outcomes) when switching from one operation to another. Item measures for volume flexibility have been adapted from existing scales (Sethi and Sethi, 1990; Upton, 1995; Gerwin, 1993; Gupta and Somers, 1992; Koste and Malhotra, 1999; D'Souza and Williams, 2000). The main strategic purpose of volume flexibility is to help cope with aggregate demand uncertainty. 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" (Upton, 1995). Volume flexibility enables a firm to effectively increase or decrease aggregate output level in response to customer demand with minimal disruption to current operations (Hayes and Wheelwright, 1984). D'Souza and Williams (2000) seek to find a middle ground by working toward a generally acceptable taxonomy of manufacturing flexibility dimensions. They build on extant literature and propose a theoretically grounded operationalization of the manufacturing flexibility construct. Our main contribution to this literature stream is that we identify and measure key sources of volume flexibility that yield improvements in performance and/or distinct competitive advantages. The various item measures considered in the construct pertaining to the volume flexibility are:

i. The organization can handle rapidly increasing production volumes
ii. The output volumes for the different products can be varied largely
iii. Level of production volume can be changed quickly
iv. Process improvement can be introduced to the manufacturing system without creating disturbances
v. Manufacturing system can operate profitably at different production volumes
vi. The quality of the goods produced is not affected by changes in volume

The response to these item measures from the sample organizations has been summarized in the Table 4.24.

Table 4.24 Item measures for volume flexibility

S. No.	Item measures for volume flexibility	Number of responses (Ni) with each score choice (Si)					Total Score, Σ(Ni*Si)	%age score
		1	2	3	4	5		
i.	The organization can handle rapidly increasing production volumes	1	7	6	25	21	238	79.33
ii.	The output volumes for the different products can be varied largely	0	11	12	29	8	214	71.33
iii.	Level of production volume can be changed quickly	0	9	17	27	7	212	70.67
iv.	Process improvement can be introduced in the manufacturing system without creating disturbances	0	6	12	36	6	222	74.00
v.	Manufacturing system can operate profitably at different production volumes	2	10	16	24	8	206	68.67
vi.	The quality of the goods produced is not affected by changes in volume	0	5	12	30	13	231	77.00

The Table 4.24 shows that within the item measures for volume flexibility, the capability of an organization to handle rapidly increasing production volumes has achieved the highest score, and closely followed by the agreement that the quality of the goods produced is not affected by changes in volume. Further, organizations agree with the fact that process improvement can be introduced in the manufacturing system without creating disturbances leading to the achievement of volume flexibility. After that, 71% of the organizations strongly agree or agree to the fact that the output volumes for the different products can be varied largely and the level of production volume can be changed quickly. However, organizations have a mixed response for the factor that defines manufacturing system can operate profitably at different production volumes. The response to six item measures has been averaged to assess the overall status of volume flexibility. This has been graphically shown in figure 4.20.

The current status of volume flexibility for the respondent organizations is very good with an average score of 0.76 and standard deviation of 0.10 only. Analysis further revealed that 51.6% of the organizations are above the average value, out of which, 23.3% is in very good range and 28.3% of the organizations possess a good status. Further, 33.3% of the organization are in fair range and possess a moderately important score. Lastly, only 15.1% the organizations are in the poor range depicting the relatively abridged level of volume flexibility.

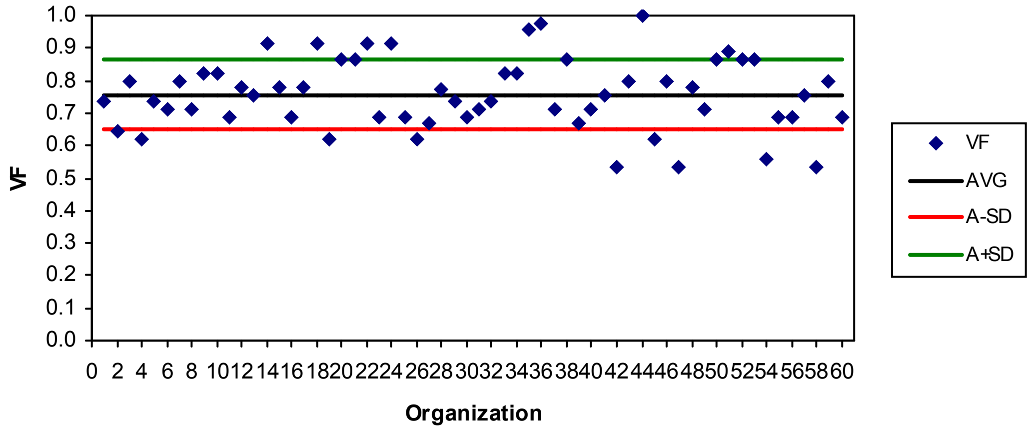


Figure 4.20 Status of volume flexibility

The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.65.

4.12.2 Modification Flexibility (MF)

Modification flexibility is defined as the capability of the manufacturing system to meet customization requests for minor design/feature product changes. 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 Malhorta, 1999). Gerwin, 1993 refers modification flexibility 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. Item measures for modification flexibility have been adapted from existing scales (Sethi and Sethi, 1990; Upton, 1995; Gerwin, 1993; Browne *et al.*, 1984; Gupta and Somers, 1992; Koste and Malhotra, 1999).

The current level of modification flexibility has been explored and examined taking into consideration various sub factors/ item measures in the construct, pertaining to its development and includes the capabilities of an organization, listed as:

i. A large number of new or modified parts and products are introduced each year
ii. An organization is capable of producing minor alterations in product design to meet customization
iii. The variety of modules/components used, enable many different products to be configured
iv. Product modifications are accomplished without incurring high transition penalties or large changes in performance outcomes
v. The time required changing to a modified product or product mix is short

The response to these item measures from the sample organizations has been summarized in the Table 4.25.

Table 4.25 Item measures for modification flexibility

S. No.	**Item measures for modification flexibility**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	A large number of new or modified parts and products are introduced each year	2	8	17	24	9	210	70.00
ii.	An organization is capable of producing minor alterations in product design to meet customization	1	2	6	34	17	244	81.33
iii.	The variety of modules/components used, enable many different products to be configured	0	6	13	26	15	230	76.67
iv.	Product modification are accomplished without incurring high transition penalties or large changes in performance outcomes	2	10	34	11	3	183	61.00
v.	The time required changing to a modified product or product mix is short	0	11	22	24	3	199	66.33

Response of the organizations to various item measures on modification flexibility as depicted in the table shows that, organization's capability of producing minor alterations in product design to meet customization has achieved the highest score, followed by strong agreement to enable configuration of many different products with the use of variety of modules/components. Further, the organizations moderately agree to the introduction of a large number of new or modified parts and products and believe that the time required, changing to a modified product or product mix is considerably high. Lastly, the factor "product modification are accomplished without incurring high transition penalties or large changes in performance outcomes" has achieved the least score leading to the connotation that cost of the modified or new product and transition penalties in course has been an area of concern for the organizations. The response to five item measures has been averaged to assess the overall status of modification flexibility. This has been graphically shown in figure 4.21.

The current status of modification flexibility for the respondent organizations is reasonably good with an average score of 0.74 and standard deviation of 0.10 only. Analysis further revealed that 60% of the organizations are above the average value, out of which, only 15% is in very good range and 45% of the organizations possess a good status. Further, 23.3% of the organization are in fair range and possess a moderately important score.

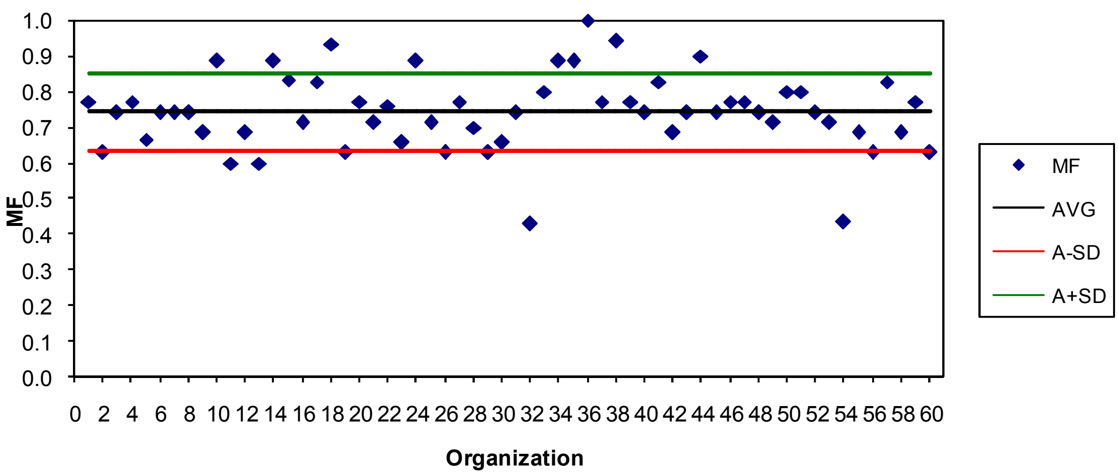


Figure 4.21 Status of modification flexibility

Lastly, 16.7% the organizations are in the poor range depicting the relatively abridged level of modification flexibility. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.675.

4.12.3 Delivery Flexibility (DF)

At the highest level are the strategic flexibilities, consisting of new product and delivery flexibilities. While tactical flexibilities relate to internal manufacturing capabilities, strategic flexibilities are external in application and focus. These flexibilities center on customer and market issues, and can change the very basis of competition in an industry. New product flexibilities is a powerful, core competence that enables the firm 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. It enables manufacturing to be recognized as a key contributor and shaper of corporate strategy. 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. Item measures for delivery flexibility have been adapted from existing scales (Sethi and Sethi, 1990; Upton, 1995; Gerwin, 1993; Narasimhan and Das, 2000).

The current level of delivery flexibility has been explored and examined taking into consideration various sub factors/ item measures in the construct, pertaining to its development and includes the capabilities of an organization, listed as:

i. The organization can handle rapid delivery of innovative products
ii. The customized products for new market creation are handled easily
iii. The performance of organization is not affected by a change in the product design
iv. The product configuration can be changed many times during the manufacturing process to accommodate customer preferences
v. Organization can provide delivery differentiation profitably

The response to these item measures from the sample organizations has been summarized in the Table 4.26.

Table 4.26 Item measures for delivery flexibility

S. No.	**Item measures for delivery flexibility**	**Number of responses (Ni) with each score choice (Si)**					**Total Score, Σ(Ni*Si)**	**%age score**
		1	**2**	**3**	**4**	**5**		
i.	The organization can handle rapid delivery of innovative products	0	6	17	25	12	223	74.33
ii.	The customized products for new market creation are handled easily	1	5	19	27	8	216	72.00
iii.	The performance of organization is not affected by a change in the product design	0	6	19	29	6	215	71.67

iv.	The product configuration can be changed many times during the manufacturing process to accommodate customer preferences	1	7	17	28	7	213	71.00
v.	Organization can provide delivery differentiation profitably	1	3	24	25	7	214	71.33

Table 4.26 shows that all the items measures depicting the status of delivery flexibility achieve total percentage score in a narrow and fairly positive range. 62% organizations agree that they can handle rapid delivery of innovative products but 47% shows their divergence to provide delivery differentiation profitably. About 32% of the respondent organizations have shown their neutral response to the different measures of delivery flexibility. However, organization ability to handle rapid delivery of innovative products has achieved the highest score amongst all item measures. All other items including organization capability to manage customized products for new market creation, non-hindrance on performance by the change in product design, frequent changes in product configuration to accommodate customer preferences, and provision of profitable delivery differentiation have scored nearly identical but significant score. The response to five item measures has been averaged to assess the overall status of delivery flexibility and graphically shown in figure 4.22. The current status of delivery flexibility for the respondent organizations is good with an average score of 0.714 and standard deviation of 0.13. Analysis further revealed that 53.3% of the organizations are above the average value, out of which, only 13.3% is in very good range and 40% of the organizations possess a good status. Further, 30% of the organization are in fair range and possess a moderately important score.

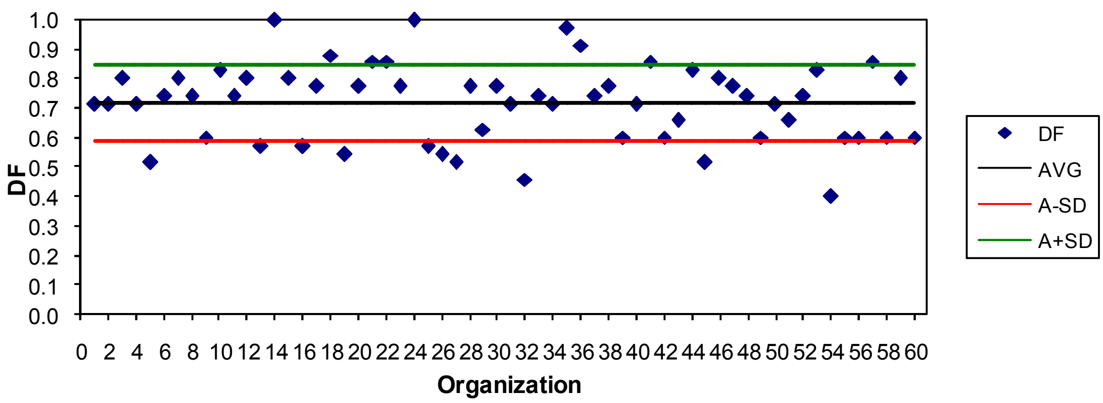


Figure 4.22 Status of delivery flexibility

Lastly, 16.7% the organizations are in the poor range depicting the relatively abridged level of delivery flexibility. The value of cronbach's alpha (α) depicting the internal reliability for the construct has come out to be 0.815.

4.13 Validation of Data

A study is valid if it measures what it claim to or in other words validity is the extent to which a measure or set of measures correctly represent the concept of study i.e. the degree to which it is free from any systematic or non-random error. It is also concerned with how well the concept is defined by the measures. The data collected through the survey has been tested for validity.

The two most widely accepted forms of validity are convergent validity and discriminant validity. Convergent validity assesses the degree to which two measures of same concept are correlated. The cronbach's alpha has been used to establish internal consistency validity i.e. the convergent validity, with 0.60 considered the acceptable value for exploratory study (Nunally, 1978). The reliability tests have been carried out using software SPSS to calculate the value of cronbach's alpha for the collected data. The values of cronbach's alpha for the factors / variables studied have been summarized in following Table 4.27.

Table 4.27 List of item measures for dependent and independent variables

	Dependent/Independent Variables	**Factors / Items included in variable**	**Cronbach's Alpha**
Dependent Variables	**Volume flexibility (VF)**	• The organization can handle rapidly increasing production volumes • The output volumes for the different products can be varied largely • Level of production volume can be changed quickly • Process improvement can be introduced to the manufacturing system without creating disturbances • Manufacturing system can operate profitably at different production volumes • The quality of the goods produced is not affected by changes in volume	0.644
	Modification flexibility (MF)	• A large number of new or modified products are introduced each year • The organization is capable of producing minor alterations in product design to meet customization • The variety of modules/components used, enable many different products to be configured • The time required to change to a modified product or product mix is short	0.675
	Delivery flexibility (DF)	• The organization can handle rapid delivery of innovative products • The customized products for new market creation are handled easily • The performance of organization is not affected by a change in the product design • The product configuration can be changed many times during the manufacturing process to accommodate customer preferences • Organization can provide delivery differentiation profitably	0.815
Independent Variables	**Technology investment in manufacturing systems (TMSYS)**	• Computer aided manufacturing (CAM) • Robotics and Group technology • Computerized numerical control machines (CNC's) • Flexible manufacturing system (FMS)	0.670

	Dependent/Independent Variables	Factors / Items included in variable	Cronbach's Alpha
	Technology investment in Manufacturing Infrastructure (TIMS)	• Soft technologies to schedule production (MRP, MRPII, KANBAN/ JIT) • Administrative technologies (ERP, ABC, OA) • Intermediate technologies (AMHS, AS/RS)	0.857
	Technology investment in Manufacturing Design (TDE)	• Computer aided design (CAD) • Computer aided engineering (CAE)/ Computer aided testing	0.796
	Supplier involvement in volume changes request (SIVCR)	• Responsiveness to schedule volume changes • Speed of capacity changeover in manufacturing system • Supplier assistance in process improvement	0.839
	Supplier involvement in modifying products (SIMP)	• Supplier involvement in managing rapid change in product variety • Supplier flexibility in minor product and process design changes • Supplier technological expertise in modifying products	0.835
	Supplier involvement in delivery changes request (SIDCR)	• Supplier responsiveness to delivery changes requests (early supplier involvement in product design) • Cross functional teams with suppliers for product design and innovation	0.769
	Supplier competencies (SCOMP)	• Supplier technological competence in design • Supplier flexibility in delivering the innovative products • Supplier financial condition and profitability • Competitive scope of the supplier • Supplier consistency	0.805
	Supplier relationship (SREL)	• Length of relationship • Level of cooperation	0.878

The Table 4.28 indicates that all the measures, which have been clubbed to form independent and dependent variables have acceptable convergent validity. Further, in order to test the internal consistency of scales, the analysis of the corrected item-to-total correlation has been done. In the analysis, the corrected item-to-total correlations have been observed for all items of a single construct for and a borderline value of 0.25 has been checked for deletion from the scale and Table 4.28 provides a summary of the purification results.

Table 4.28 Internal consistency and convergent validity of data

Construct	No. of Items	Mean	Variance	Minimal item to total correlation	Cronbach's alpha (α)
SIVCR	4	3.76	0.312	0.65	0.644
SIMP	4	3.69	0.319	0.70	0.675
SIDCR	5	3.28	0.688	0.73	0.815
SCOMP	6	3.89	0.339	0.70	0.670
SREL	3	4.41	0.370	0.84	0.857
TDE	2	3.45	1.282	0.90	0.796
TMSYS	8	3.06	0.630	0.49	0.839
TIMS	3	3.31	0.820	0.77	0.835
VF	6	3.78	0.299	0.50	0.769
MF	4	3.71	0.286	0.34	0.805
DF	5	3.58	0.430	0.54	0.878

Discriminant validity, the second major type of construct validity, refers to the principle that the indicators for different constructs should not be so highly correlated as to lead one to conclude that they measure the same thing. This would happen if there were definitional overlaps between constructs. Discriminant validity analysis refers to testing statistically whether two constructs differ (as opposed to testing convergent validity by measuring the internal consistency within one construct, as Cronbach's alpha does).

An eight factor correlated model representing each of the elements has been used to examine discriminant validity. The within-group and between-group variances for all the constructs are contained in table. The ten elements are listed in the header row and column. The diagonal cells contain the within-group variances, the off-diagonal cells in the lower triangle contain the between-group variances, and the off-diagonal cells in the upper triangle represent correlations among the constructs. As can be seen in the Table 4.29, the within-group variances of any two constructs exceed the variance between those two constructs, thereby supporting discriminant validity.

Table 4.29 Discriminant validity testing matrix

	SIVCR	SIMP	SIDRC	SCOMP	SREL	TDE	TMSYS	TIMGT
SIVCR	**0.312**	0.588	0.519	0.634	0.527	0.308	0.350	0.514
SIMP	0.186	**0.319**	0.659	0.462	0.386	0.413	0.543	0.368
SIDRC	0.241	0.309	**0.688**	0.414	0.122	0.532	0.537	0.522
SCOMP	0.207	0.152	0.200	**0.339**	0.615	0.346	0491	0.434
SREL	0.175	0.130	0.060	0.213	**0.354**	0.128	0.136	0.044
TDE	0.195	0.264	0.500	0.228	0.086	**1.282**	0.565	0.358
TMSYS	0.155	0.243	0.353	0.336	0.064	0.507	**0.627**	0.580
TIMGT	0.262	0.189	0.394	0.230	0.024	0.369	0.418	**0.829**

Hence this data has been tested for convergent and discriminant validity and found to be free from any systematic or non-random error.

4.14 Data Analysis

4.14.1 Bivariate Correlation Analyses and Scatter Plot

As a precursor to canonical correlation analysis, the pair-wise correlations between variables and distribution of variables were examined. Further, variables were selected to avoid problems of multicollinearity. The bivariate correlation matrix is tabulated (Table

4.30) to find out the variables that are highly correlated. Analysis of the data has revealed that the correlations between the variables are in moderate range, with no highly significant association between the variables.

Table 4.30 Correlation matrix

	SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS
SIVCR	1	.588**	.519**	.634**	.527**	.308*	.350**	.514**
SIMP	.588**	1	.659**	.462**	.386**	.413**	.543**	.368**
SIDCR	.519**	.659**	1	.414**	.122	.532**	.537**	.522**
SCOMP	.634**	.462**	.414**	1	.615**	.346**	.491**	.434**
SREL	.527**	.386**	.122	.615**	1	.128	.136	.044
TDE	.308*	.413**	.532**	.346**	.128	1	.565**	.358**
TMSYS	.350**	.543**	.537**	.491**	.136	.565**	1	.580**
TIMS	.514**	.368**	.522**	.434**	.044	.358**	.580**	1

*** Correlation is significant at the 0.01 levels. ; * Correlation is significant at the 0.05 levels.*

The correlation matrix depicting the association between the independent and dependent variabes has also been established and presented in the Table 4.31. The bivariate correlation matrix potrays the relationship between different variables that helped in the analyzing the variability of correlation. The relationship among the various independent and dependent variables have been further studied to select the group of variables for canonical correlation analysis. Volume flexibility has been found to have a strong positive association with the SIVCR, SIMP and TIMS at p = 0.000. Further, modification flexibility has established a significant positive association with SIVCR(p=0.000) and SIMP (p=0.01). SCOMP, SIVCR and SIMP at p=0.000 has been found to be significantly associated with the delivery flexibility.

Table 4.31 Correlation between Independent (sourcing practices and AMT) and dependent variables (flexibilities)

	SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS
VF	.464**	.483**	.276*	.419**	.119	.237	.473**	.532**
MF	.479**	.435**	.244	.388**	.211	.328*	.306*	.378**
DF	.468**	.451**	.177	.550**	.317*	.121	.296*	.248

*** Correlation is significant at the 0.01 levels. ; * Correlation is significant at the 0.05 levels.*

Further, scatter plot has been developed for examining the bivariate relationship between the dependent and independent variables, representing the corresponding joint values of the variables for a given case. The pattern of points represents the relationship between the variables. A strong organization of the points along the straight line characterizes a linear relationship or correlation. A curved set of relationship may denote a non-linear relationship, which can account for a seemingly random pattern of points, indicating no relationship. The scatter plot shown in figure 4.23 portrays the bivariate relationship between the set of variables. The varying relationship has been observed within the independent and between the independent and dependent variables, as depicted by the strong organization of the points along the straight line.

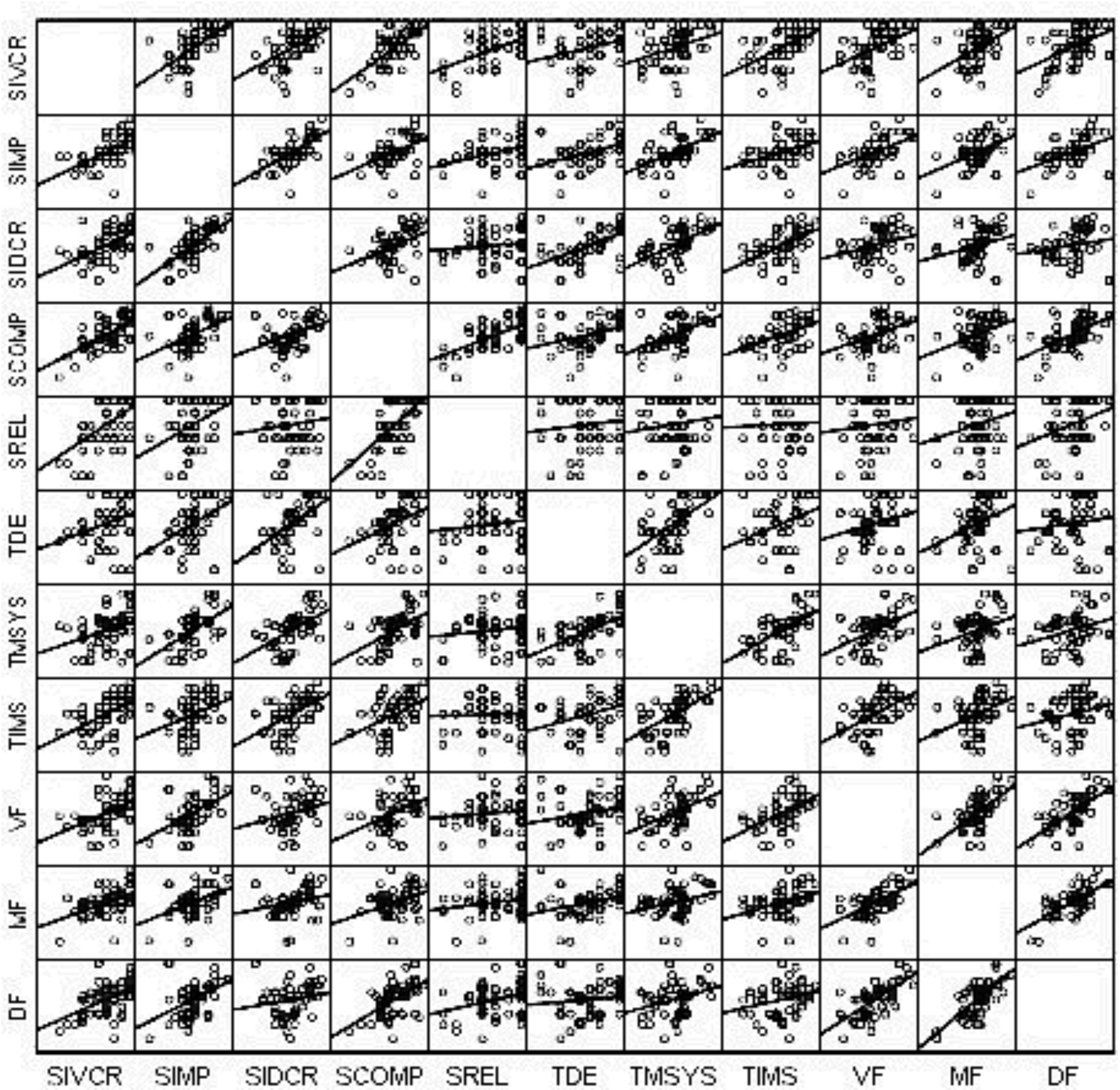


Figure 4.23 Bivariate relationship between the dependent and independent variables

Taking into consideration the associations between the variables and effect of multicollinearity, two variables (SREL and TDE) have been dropped from the empirical canonical correlation analysis, after observing the relatively low impact on the different flexibilities or multicollinearity problem. 'Supplier relationship, SREL has a strong association with SCOMP($r = 0.615$, $p = 0.000$) but comparative feeble association with dependent variables in the group. For similar reasons, TDE has been kept out from the further analysis.

4.14.2 Canonical Correlation Analyses – Stage 1(VF, MF, DF)

The primary objective of data analysis in this research work is to examine the relationship between independent and dependant variables. Since the interest centered on investigating the relationships between a set of multiple dependent and multiple independent variables with little prior knowledge of such relationships, canonical correlation analysis has been considered to be the most appropriate and powerful multivariate statistical technique (Hair *et al.* 1998) to use. In this research work, the sample size is 60, so maximum of six variables can be taken each for dependent and independent variate in canonical analysis.

The canonical correlation analysis has been conducted in two stages. The first stage results presented in column 1 of Table 4.32 indicated a significant canonical correlation function (r = 0 .695; p < 0.001) between set of several of the sourcing practices and AMT, and different manufacturing flexibilities.

Table 4.32 Canonical correlation analysis results with stability analysis - I

	Results with all variables		**Results after deletion of**					
			SIVCR	**SIMP**	**SIDCR**	**SCOMP**	**TMSYS**	**TIMS**
Canonical Correlation	**0.695**		0.687	0.641	0.648	0.691	0.692	0.667
Canonical Root	**0.483**		0.471	0.410	0.419	0.477	0.478	0.444
f statistic	0.00		0.00	0.01	0.02	0.00	0.00	0.00
DEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
Volume flexibility	-0.668	-0.961	-0.966	0.973	0.964	-0.971	-0.952	-0.878
Modification flexibility	-0.553	-0.761	-0.779	0.783	0.804	-0.789	-0.804	-0.790
Delivery flexibility	-0.563	-0.810	-0.811	0.735	0.760	-0.744	-0.829	-0.938
Shared Variance	0.737		0.732	0.701	0.718	0.706	0.747	0.758
Redundancy Index	0.356		0.346	0.288	0.302	0.338	0.357	0.338
INDEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
SIVCR	-0.519	-0.747	N.A.	0.790	0.793	-0.737	-0.755	-0.781
SIMP	-0.518	-0.746	-0.753	N.A.	0.792	-0.738	-0.752	-0.769
SIDCR	-0.281	-0.405	-0.407	0.452	N.A.	-0.419	-0.403	-0.371
SCOMP	-0.480	-0.690	-0.701	0.692	0.702	N.A.	-0.706	-0.804
TMSYS	-0.454	-0.653	-0.663	0.724	0.708	-0.670	N.A.	-0.607
TIMS	-0.504	-0.725	-0.732	0.831	0.809	-0.767	-0.715	N.A.
Shared Variance	0.451		0.440	0.504	0.581	0.460	0.462	0.471
Redundancy Index	0.218		0.208	0.208	0.244	0.220	0.221	0.210

The redundancy indices were 0.356 and 0.218 for the dependent and independent canonical variates respectively. The redundancy index indicates the amount of variance in a canonical variate explained by the other canonical variate in the canonical function. To assess the validity of the canonical loadings, because of the modest sample size stability runs were made by dropping one variable at a time and re-executing the canonical correlation analysis. Of interest are the stability of the canonical loadings and the statistical significance of the univariate and step down *F* tests for the canonical correlation function. Canonical loadings measure the correlation between the individual independent and dependent variables and their respective canonical variates, and are similar in interpretation to factor loadings. Columns 2, 3, 4, 5, 6 and 7 in Table 4.32 show the results of these stability runs corresponding to the deletion of SIVCR, SIMP, SIDCR, SCOMP, TMSYS, TIMS respectively. Stability runs when SIMP and SIDCR (column 3 and 4) were dropped resulted in canonical loadings markedly different from the previous runs. Therefore, a second stage canonical correlation analysis has been run in two stages considering the combination of tactical and strategic level flexibility. This includes the deleting of modification flexibility and volume flexibility separately in different runs from the canonical correlation analysis for further examination.

4.14.3 Canonical Correlation and Regression Analyses – Stage 2(VF, DF)

Firstly, a second stage canonical correlation analysis has been run after deleting modification flexibility. The results of second stage canonical correlation analysis that are presented in Table 4.33 represent a general improvement over stage 1 results in terms of overall t and canonical loadings. A strong and statistically significant (r = 0.687; $p <$ 0.001) canonical correlation has been found between the dependent set of delivery and volume flexibility and the independent set of sourcing variables and AMT variables. The redundancy indices were 0.388 and 0.210 for the dependent and independent canonical variates, respectively. The canonical loadings for on the independent variate ranged from 0.381 to 0.734. Delivery flexibility and volume flexibility also loaded strongly (0.961 and 0.850) on the dependent variate. The cross loadings of independent variables from this analysis indicate that SIMP and SIVCR have largest loading on the dependent set with cross loading of 0.511 and 0.504. The next major factors affecting this set of dependent variables are SCOMP and TIMS with cross loading of 0.503 and 0.471. Similarly the cross loadings of all other factors are presented against them in the Table 4.33. To assess the validity of the canonical loadings, stability runs were made by dropping one variable at a time and re-executing the canonical correlation analysis. As can be seen from the results in Columns 2, 3, 4, 5, 6 and 7 in Table 4.33, the results indicated the stability of the canonical loadings.

Table 4.33 Canonical correlation analysis results with stability analysis - II

	Results with all variables		Results after deletion of					
			SIVCR	**SIMP**	**SIDCR**	**SCOMP**	**TMSYS**	**TIMS**
Canonical Correlation	**0.687**		0.681	0.631	0.636	0.678	0.684	0.665
Canonical Root	**0.471**		0.463	0.398	0.404	0.459	0.467	0.442
f statistic	0.00		0.00	0.00	0.00	0.00	0.00	0.00
DEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
Volume flexibility	-0.660	-0.961	-0.963	-0.980	-0.969	-0.991	-0.950	-0.874
Delivery flexibility	-0.584	-0.850	-0.845	-0.806	-0.834	-0.762	-0.870	-0.947
Shared Variance	0.823		0.821	0.805	0.817	0.782	0.829	0.830
Redundancy Index	0.388		0.381	0.320	0.330	0.359	0.387	0.367
INDEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
SIVCR	-0.504	-0.734	N.A.	-0.788	-0.789	-0.720	-0.741	-0.764
SIMP	-0.511	-0.744	-0.750	N.A.	-0.802	-0.739	-0.749	-0.759
SIDCR	-0.262	-0.381	-0.386	-0.425	N.A.	-0.401	-0.378	-0.355
SCOMP	-0.503	-0.732	-0.735	-0.766	-0.780	N.A.	-0.748	-0.816
TMSYS	-0.446	-0.650	-0.657	-0.725	-0.709	-0.686	N.A.	-0.601
TIMS	-0.471	-0.685	-0.695	-0.780	-0.754	-0.751	-0.672	N.A.
Shared Variance	0.444		0.433	0.504	0.589	0.452	0.453	0.463
Redundancy Index	0.210		0.201	0.201	0.238	0.208	0.212	0.201

For a closer examination of relationships between individual dimensions of flexibility and the sourcing variables, two separate regression analyses were run, using delivery flexibility and volume flexibility as dependent variables and the sourcing practices and AMT variables from the canonical analysis as the independent variables. The multivariate test statistics (see Table 4.34) are statistically significant *(p* < 0.01). SCOMP ($p < 0.01$) and SIMP ($p < 0.05$) found to be positively related to delivery flexibility. TIMS ($p < 0.01$) and SIMP ($p < 0.05$) has a positive relationship with volume flexibility.

The Table 4.34 shows that the multiple correlation coefficient (R), for volume flexibility, is 0.624 (R^2 = 0.389) and the adjusted R^2 is 0.357, leading to the connotation that 35.7% of the variance in volume flexibility can be predicted from ‘supplier involvement in modifying products’, ‘supplier competencies’ and ‘technology investment in manufacturing infrastructure’ combined. As the results indicate that, only ‘supplier involvement in modifying products’ and technology investment in manufacturing infrastructure are statistically significant, but other variables will also add a little to the development of volume flexibility. The Table 4.34 shows that F-probability is less than 0.001 and is significant. This indicates that the combination of the independent variables significantly predict the volume flexibility. The standardized beta coefficients are interpreted similarly to correlation coefficients or factor weights. The t value indicates that whether variable is significantly contributing to the equation for predicting dependent variable from the whole set of dependent variables.

Table 4.34 Results of regression analysis between independent (sourcing practices and AMT) and dependent variables (manufacturing flexibility)

Dependent Variable – Volume flexibility	**Multiple *R***	R^2	**Adjusted** R^2	***F* probability**	**Durban Watson statistic**	
	0.624	0.389	0.357	0.000	1.854	
Independent Variables	**B**	**Beta**	**Standard error**	***t*-value**	**Significance of *t***	**Tolerance/ VIF**
SIMP	0.279	0.288	0.116	2.394	**0.020**←	0.752/ 1.33
SCOMP	0.116	0.124	0.117	0.997	0.323	0.706/ 1.41
TIMS	0.223	0.372	0.071	3.140	**0.003** ←	0.776/ 1.29
Dependent Variable - Delivery flexibility	**Multiple *R***	R^2	**Adjusted** R^2	***F* probability**	**Durban Watson statistic**	
	0.594	0.353	0.318	0.000	1.899	
Independent Variables	**B**	**Beta**	**Standard error**	***t*-value**	**Significance of *t***	**Tolerance/ VIF**
SIMP	0.300	0.258	0.144	2.085	**0.042** ←	0.752/ 1.33
SCOMP	0.505	0.449	0.144	3.510	**0.001** ←	0.706/ 1.41
TIMS	-0.030	-0.042	0.088	-0.345	0.731	0.776/ 1.29

It is important to note that all the variables are being considered together when these values are computed. Therefore, deleting one of the independent variable, that is not significant, can affect the levels of significance for other dependent variables. The tolerance for each of these variables is > 0.643(1-0.357), indicating that there is no problem of multicollinearity (overlap between dependent variables). Similarly for delivery flexibility the value of multiple R is 0.594 (R^2 = 0.353) and the adjusted R^2 is 0.318, leading to the connotation that 31.8% of the variance in delivery flexibility can be predicted from 'supplier involvement in modifying products', 'supplier competencies' and 'technology investment in manufacturing infrastructure' combined. As the results indicate that, only 'supplier competencies' are statistically significant at $p < 0.01$ and thus play a major role in developing delivery flexibility along with the 'supplier involvement in modifying products' ($p < 0.05$).

Further, multiple linear regression analysis has also been performed taking in to account a set of all the independent variables and each dependent variable individually, through step-wise method, for depicting the clear and base understanding of the output results. The analysis of the results revealed nearly the same output as initiated in the linear regression analysis (enter method). The role of SIMP and TIMS has been found to be positively significant in case of volume flexibility. However, SIDCR has emerged with a significant but negative relation with volume flexibility. In case of delivery flexibility, the SCOMP construct has positively influenced the achievement of delivery flexibility. The step wise linear regression analysis has been performed for avoiding the problems posed by multicollinearity in SPSS software. The details of the step wise regression analysis have been presented in the Appendix E.

The research provides the first empirical evidence of such a relationship with a relative choice among sourcing practices and AMT for developing different manufacturing flexibilities in large and medium scale organizations in north India. The role of sourcing practices and AMT has been explored and examined for developing the flexibilities at tactical and strategic level of an organization. The result shows that technology investment in manufacturing infrastructure, explicitly the use of soft, administrative and intermediate technologies have resulted in strengthening the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly and profitably. The use of soft technologies to schedule production (MRP, MRPII, KANBAN/JIT etc), administrative technologies (ERP, ABC, OA) and intermediate technologies (AMHS and AS/RS) have shown a positive relation with volume flexibility of the organization. Supplier involvement in modifying products has also significantly shown a positive impact in managing the frequent volume fluctuations without sacrificing the quality of the different products after the TIMS. Interestingly, association with supplier base on long term basis and investment in manufacturing design are weakly correlated with volume flexibility. However, there is a strong correlation among various supplier capabilities. The results depicts that supplier ability to respond to order delivery changes has a positive relationship with volume flexibility. Competitive pressures require manufacturing to respond efficiently to volume changes in different product/ market segments necessitating volume flexibility capabilities. To achieve such volume flexibility capabilities sourcing practices should stress selection and development of a supply-base with quick reaction times to delivery change requests and streamlining decisions for better control and co-ordination of supply chain processes within an organization. Quick responsiveness to order delivery change requests correlates strongly with responsiveness to order volume change requests, which in turn, are strongly correlated with supplier ability to modify products, as well as with supplier capabilities for involvement in product and process design.

The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization. The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility, as the competencies provided by supplier network contain a high degree of knowledge, access to advanced technology and are those most complimentary to in house core competencies including innovation in design and development. Supplier involvement in managing minor product and process changes for an organization played an imperative role as a prerequisite in developing delivery flexibility.

It has been found that a strong positive correlation exists between different flexibilities (0.65 or more) in the study. Another issue of managerial interest concerns the way different flexibilities influence one another and whether organizations should acquire certain flexibilities as a pre-requisite for developing others. It is useful to speculate on possible synergies among different types of flexibilities and their implications for technology and sourcing. A company with superior modification flexibility capabilities is likely to have workers, systems and an organizational culture, which support the creation and acceptance of change. Familiarity with incremental change could make it relatively easier for such a company to design and manufacture entirely new products and attain strong delivery flexibility capabilities. A company with high delivery flexibility may be able to operate more economically, if it has already developed a high degree of volume flexibility. Similarly, a company possessing high volume flexibility capabilities may be able to better cope with the market fluctuations of a wide product mix and thus provide a foundation for the development of mix flexibility capabilities and can also be studied separately. Customization performance could depend on performing well in all flexibility dimensions.

4.14.4 Canonical Correlation and Regression Analyses – Stage 2(MF, DF)

Secondly, a second stage canonical correlation analysis has been run after deleting volume flexibility. The results of the canonical correlation analysis are presented in Table 4.35. A strong and statistically significant ($r = 0.649$; $p < 0.001$) canonical correlation has been found between the dependent set of delivery and modification flexibility and the independent set of sourcing variables and AMT variables. To assess the validity of the canonical loadings, because of the modest sample size stability runs have been made by dropping one variable at a time and re-executing the canonical correlation analysis. Of interest are the stability of the canonical loadings and the statistical significance of the univariate and step down *F* tests for the canonical correlation function. Canonical loadings measure the correlation between the individual independent and dependent variables and their respective canonical variates, and are similar in interpretation to factor loadings. Columns 3, 4, 5, 6, 7 and 8 in Table 4.35 show the results of these stability runs corresponding to the deletion of SIVCR, SIMP, SIDCR, SCOMP, TMSYS, TIMS respectively. The canonical loadings for the independent variate ranged from 0.374 to 0.798. Delivery and modification flexibility also loaded strongly (0.988 and 0.808) on the dependent variate.

The computation of canonical cross-loadings has been suggested as an improved method to interpret the results in canonical correlation analysis as compared to canonical weights or canonical loadings (Hair *et al.*, 1995). This procedure involves correlating each of the original observed dependent variables directly with the independent canonical variate, and vice versa. Cross-loadings provide a more direct measure of the dependent–independent variable relationships by eliminating an intermediate step involved in conventional loadings. The cross loadings of independent variables from the analysis indicate that supplier involvement in volume changes request, supplier involvement in modifying products and supplier competencies have the largest contribution to the dependent set that is modification and delivery flexibility combined with cross loading of 0.523 and above.

The redundancy indices have been 0.342 and 0.187 for the dependent and independent canonical variates, respectively. The redundancy index indicates the amount of variance in a canonical variate explained by the other canonical variate in the canonical function. As can be seen, the redundancy index for the dependent variate is substantial. The independent variate, however, has a markedly lower redundancy index (0.187), although in this case, because there is a clear delineation between dependent and independent variables, this lower value is not unexpected or problematic. The low redundancy of the independent variate results from the relatively low-shared variance in the independent variate (0.418), not the canonical R^2.

Table 4.35 Canonical correlation analysis results with stability analysis - III

	Results with all variables		Results after deletion of					
			SIVCR	SIMP	SIDCR	SCOMP	TMSYS	TIMS
Canonical Correlation	**0.649**		0.640	0.595	0.606	0.607	0.649	0.646
Canonical Root	**0.421**		0.409	0.354	0.367	0.368	0.421	0.417
f statistic	0.00		0.00	0.00	0.00	0.00	0.00	0.00
DEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
Modification flexibility	-0.609	-0.808	-0.783	-0.799	-0.817	-0.913	-0.808	-0.789
Delivery flexibility	-0.630	-0.988	-0.993	-0.990	-0.985	-0.934	-0.988	-0.992
Shared Variance	0.814		0.800	0.809	0.819	0.852	0.814	0.803
Redundancy Index	0.342		0.328	0.286	0.301	0.314	0.342	0.336
INDEPENDENT VARIATE	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**					
SIVCR	-0.523	-0.782	N.A.	-0.829	-0.820	-0.844	-0.763	-0.759
SIMP	-0.525	-0.783	-0.729	N.A.	-0.779	-0.790	-0.726	-0.723
SIDCR	-0.250	-0.374	-0.305	-0.335	N.A.	-0.372	-0.311	-0.305
SCOMP	-0.535	-0.798	-0.854	-0.916	-0.894	N.A.	-0.838	-0.844
TMSYS	-0.334	-0.499	-0.484	-0.526	-0.520	-0.537	N.A.	-0.481
TIMS	-0.338	-0.505	-0.436	-0.481	-0.484	-0.551	-0.447	N.A.
Shared Variance	0.418		0.356	0.429	0.517	0.413	0.422	0.427
Redundancy Index	0.187		0.146	0.152	0.190	0.152	0.177	0.179

For a closer examination of relationships between individual dimensions of flexibility and the sourcing and technology variables, two separate regression analysis have been run, using delivery flexibility and modification flexibility as dependent variable and variables with highest cross-canonical loadings from the canonical analysis as the independent variables. The multivariate test statistics have found a positive significance (Table 4.36) for SCOMP ($p < 0.001$) and SIMP ($p < 0.001$) in relation to delivery and modification flexibility.

The Table 4.36 shows that the multiple correlation coefficient (R), using the independent variables with highest loadings simultaneously for modification flexibility, is 0.591 (R^2 =0.349) and the adjusted R^2 is 0.314, leading to the connotation that 31.4% of the variance in modification flexibility can be predicted from ‘supplier involvement in modifying products’, ‘supplier competencies’ and ‘supplier involvement in volume changes requests' combined. As the results indicate that, only supplier involvement in modifying products is statistically significant, but other variables will also add a little to the development of modification flexibility. The table shows that F-probability is less than 0.001 and is significant. This indicates that the combination of the independent variables significantly predict the modification flexibility. The standardized beta coefficients are interpreted similarly to correlation coefficients or factor weights. The t value indicates that whether variable is significantly contributing to the equation for predicting dependent variable from the whole set of dependent variables.

Table 4.36 Results of regression analysis between independent (sourcing practices and AMT) and dependent variables (manufacturing flexibility)

Dependent Variable - Modification Flexibility	**Multiple *R***	**R^2**	**Adjusted R^2**	***F* probability**	**Durban Watson statistic**	
	.591	.349	.314	0.000	1.815	
Independent variables	**B**	**Beta**	**Standard error**	***t*-value**	**Significance of *t***	**Tolerance / VIF**
SIMP	0.282	0.203	0.338	2.509	**0.015**←	0.682/ 1.46
SCOMP	0.105	0.114	0.129	0.918	0.363	0.741/ 1.35
SIVCR	0.191	0.131	0.226	1.460	0.150	0.654/ 1.53
Dependent Variable - Delivery flexibility	**Multiple R**	**R^2**	**Adjusted R^2**	**F probability**	**Durban Watson statistic**	
	0.597	0.356	0.321	0.000	1.935	
Independent variables	**B**	**Beta**	**Standard error**	***t*-value**	**Significance of *t***	**Tolerance / VIF**
SIMP	0.249	0.155	0.215	1.602	0.115	0.682/ 1.46
SCOMP	0.441	0.198	0.392	2.797	**0.007**←	0.741/ 1.35
SIVCR	0.109	0.180	0.093	0.606	0.547	0.654/ 1.53

It is important to note that all the variables are being considered together when these values are computed. Therefore, deleting one of the independent variable, that is not significant, can affect the levels of significance for other dependent variables. Similarly for delivery flexibility the value of multiple R is 0.597 ($R^2 = 0.356$) and the adjusted R^2 is 0.321, leading to the connotation that 32.1% of the variance in delivery flexibility can be predicted from supplier involvement in modifying products, supplier competencies and supplier involvement in volume changes requests combined. As the results indicate that, only supplier competencies are statistically significant at $p < 0.01$ among the group of independent variables chosen for regression analysis and thus play a major role in developing delivery flexibility. Further, multiple linear regression analysis has also been performed taking in to account a set of all the independent variables and each dependent variable individually, through step-wise method, for depicting the clear and base understanding of the results. The role of SIMP and SIVCR has come out with a positive significant relation with the modification flexibility and are in line with the outcome achieved earlier. The SCOMP construct positively influence the achievement of delivery flexibility. The details of the analysis have been presented in the Appendix E and F.

The role of supplier involvement in modifying products, explicitly the supplier assistance in minor product and process design changes, specific technological capabilities of the supplier and supplier involvement in managing the rapid changes in product variety have resulted in strengthening the organization capabilities to manage the modification flexibility. It has been observed that organizations have shifted their mind focus towards the increased use of different sourcing practices for achieving the modification flexibility and in course competitiveness in the market place. However, the role of supplier involvement in managing volume changes requests, as a prerequisite and supplier competencies in terms of level of manufacturing flexibility, financial condition and profitability, consistency and competitive scope have positively influenced the development of modification flexibility. Adoption of advanced manufacturing technologies has not significantly but moderately impacted the modification flexibility dimension. However, the strategic use of organizational infrastructural resources has shown some positive trends towards the attainment of modification flexibility.

The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization. Supplier competencies and auditing capabilities including their competitive scope, financial condition and profitability, flexibility in delivering the innovative products and technological competence have played a vital role in developing delivery flexibility. The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility, as the competencies provided by supplier network contain a high degree of knowledge, access to advanced technology and are those most complimentary to in house core competencies including innovation in design and development. Supplier involvement in managing minor product and process changes for an organization played an imperative role as a prerequisite in developing delivery flexibility.

It has been found that a strong positive correlation exists between modification and delivery flexibility (0.706) of this study. However, modification flexibility, being a tactical level capability, has to be attained prior to developing delivery flexibilities. Hence, a sourcing strategy for enhancing modification flexibility has to be implemented in advance of similar actions to support the development of delivery flexibility. These arguments suggest that there may be a need to develop and deploy certain sourcing actions prior to deploying others.

This study investigated the role of sourcing practices and AMT in achieving manufacturing flexibilities. Manufacturing flexibility has been described as a hierarchical, multi-dimensional capability. Empirical evidence has been presented to support relationships between specific sourcing practices and AMT and different tactical and strategic level flexibilities. These relationships indicate the usefulness of treating manufacturing flexibility as a multi dimensional concept. The findings suggest that sourcing practices may be quite important to manufacturing organizations trying to compete through flexibility competence at tactical and strategic level. Supplier involvement in modifying product and process design, supplier's strategic competencies and technology investment in manufacturing infrastructure has been found to benefit delivery and volume flexibilities. Cross-functional teams have been found to be the key area of interest for achieving manufacturing flexibility. Supplier involvement in modifying product and process design has also been found to benefit modification flexibility. The role of implementing the soft, intermediate and hard technologies have been explored and found less significant when compared to the sourcing practices, which leads to the connotation that strategic shift has been witnessed towards the virtual organizations. The role of human factor has been not included in the preview of this study and hence a critical analysis is required to establish its concern in developing manufacturing flexibilities.

4.15 Learning Issues

The various learning issues have been derived on the basis of descriptive and empirical analyses of the primary data collected through the questionnaire survey and presented below.

4.15.1 Learning Issues based on Descriptive Analysis

Business strategy and initiatives

- 'Customer focus and commitment' has been considered as the highly important business initiative by majority of the organizations.

- The role of ‘manufacturing technology’ and ‘win-win situations with suppliers’ has been equally and significantly targeted by 81% of the organizations.
- Organizations have largely considered the importance of inducing flexibility in the manufacturing and design as an instrument for achieving competitiveness.
- 77% of the organizations have given a significant importance to the attainment of adjustments in production capacity quickly.
- Flexibility in offering large degree of product features and variety has been considered significantly important by 65% of the organizations.
- Introduction of rapid design changes in the products have been felt considerably important by 50% of the organizations.
- Majority of the organizations have given the foremost priority to the achievement of quality conformance and reliability.
- ‘Quality of the product’ and ‘new product introductions’ has been found to be the highly important performance parameter for achieving competitive excellence by large segment of the respondent organizations.
- Achievement of flexibility in manufacturing has been found to be a significantly important by 75% of the organizations.
- 78% of the organizations have achieved the substantial improvement in their competitive position in the recent years of their business operations.

Technology adoption

- The survey results depict the mixed response for the level of adoption of new technology by the organizations.
- 68% of the organizations have an agreement that manufacturing and design technologies played a significant role in their success.
- The need to improve the flexibility in the manufacturing system and fostering of next generation technology has been the main rationale for new technology adoption in 50% of the organization.
- Increase in product quality in terms of performance and features have been found to be the fundamental factor for augmenting the adopting of new technology in 90% of the organizations. Additionally, more than 88% of the organizations adopt new technology for improving the productivity level.

- 65% of the organizations have an agreement that infrastructural technologies played a significant role in their success.
- High cost of new technology has been considered as a main barrier for its adoption by 70% of the organizations.
- 60% of the organizations adopt new technology in order to reduce their dependency on external suppliers.
- The lack of information on new technology and customer non-responsiveness to new products has little to moderate effect for adopting the new technology in 23% of the organizations.
- Around 85% of the organizations have considerably increased the performance and features of their products by the adoption of new technology.
- Speed of delivery and number of customized product offerings has significantly increased as a result of new technology adoption in 79% of the organizations.
- The new product lead-time has remained unaltered or moderately increased in the 70% of the organizations.
- Analysis of flexibility aspect has revealed that tactical and strategic level flexibilities have moderately to significantly increase in 69% of the organizations.
- The cost of the existing and future product innovations have shown an upward trend, which can be resulted due to the high cost of technology acquisition in short term.
- 65% organizations have revealed a moderate improvement in the market share and net profit as a result of adopting new technology.

Sourcing practices

- 'Reduction in operating cost and risk of business' has been considered as the primary factor for adopting the various sourcing practices by 85% of the organizations and followed by 'adaptability to customer's needs and requirement' in 65% of the organizations.
- 60% of the organizations have an agreement that the outsourcing of manufacturing facilities has played a moderate role in their business success.
- 61% of the organizations have an agreement that an involvement of supplier(s) in design and new product development process has played a moderate role in managing the market fluctuations.

- Supplier involvement has significantly and positively influenced the outcome of the organizations in terms of added flexibility and delivery aspects.
- In 86% of the organizations, the capacity and capability to achieve volume and modification flexibility has been significantly improved due to the adoption of various sourcing practices.
- Delivery of innovative products has seen a moderate upside movement with the adoption of sourcing practices in 55% of the organizations.
- More than 50% of the organizations have observed a moderate increase in the delivery speed and reliability due to the adoption of various sourcing practices.
- ‘Competitive scope of the supplier’ has been considered as the most important factor in the supplier selection criteria by most of the organizations.
- Flexibility dimensions including ‘supplier responsiveness to the demand fluctuations’ and ‘supplier modification capabilities’ have significantly influenced the supplier selection process in most of the organizations.
- An organization’s ability to produce a quality product at a reasonable cost and in a timely manner is heavily influenced by its suppliers’ capabilities.
- ‘Supplier technological competencies’ has emerged as the determining factor for the organization’s success.
- Most of the organizations have considerably focused on the delivery aspect of the supplier in terms of consistency and speed.
- Supplier’s integration in manufacturing has low to moderate impact on an organization performance in terms of loss of control and confidentiality dependency.
- The majority of the organizations strive to establish a long-term strategically managed relationship with key suppliers, which in turn have a positive impact on the organization performance.

Manufacturing flexibility

- The current status of manufacturing flexibility for the manufacturing organizations is very good with an average score of 0.76 and standard deviation of 0.10 only. Further, the status of manufacturing flexibility in 15% of the organizations is very good, which indicates their ability to achieve the flexibility at operational, tactical and strategic level.

- 34% organizations attain a good status and have a score between 0.77 to 0.89.These organizations moderately agree to achieve the various dimensions of manufacturing flexibility at operational and tactical level, but have comparatively low score at strategic level.
- In 40% organizations, the status of manufacturing flexibility is fair. These organizations need to strengthen their manufacturing capabilities at all levels for effectively and efficiently achieve the flexibility aspect.
- In 11% organizations, the status of manufacturing flexibility is in poor state. These organizations are weak and ill prepared and needs a major improvement plan urgently at all levels for achieving different manufacturing flexibilities.
- Most of the organizations have a capability to introduce process improvements in the manufacturing system. Further, 85% of the organizations have a capacity to produce large number of product categories in the manufacturing system.
- Around 72% of the organizations have a moderate to high capacity to handle volume changes in the manufacturing system in which 23% of the organizations have a uppermost agreement to handle these demand fluctuations.
- 77% of the organizations believes that they can handle the different delivery sequences quickly and efficiently to satisfy customer demands and creating new markets.
- Around two third of the organizations can quickly changeover the manufacturing system to a different product mix.
- 60% of the organizations agree to the fact that the product configurations can be changed many times during the manufacturing process to accommodate customer preferences.
- The responsiveness of the organizations to the customer demands and operating efficiently at different levels of output has emerged as the most important, amongst flexibility-oriented tasks.
- The delivery of innovativeness in designing of new products has been an area of concern within the organizational competencies. Only 55% of the organizations have the capability to put new product design into production quickly.
- The sourcing practices are leading in flexibility, delivery and net profit aspects in contrast to new technology, which leads moderately for quality and market share.

- Cross-functional teams have been found to be the key area of interest for achieving manufacturing flexibility.

Volume flexibility

- The current status of volume flexibility for the manufacturing organizations is very good with an average score of 0.76 and standard deviation of 0.10 only.
- 79% of the organizations strongly agree that they have the capabilities to handle rapidly increasing production volumes.
- 74% of the organizations agree that process improvement can be introduced in the manufacturing system without creating disturbances.
- The quality of the goods produced is not affected by changes in volume in 72% of the organizations.
- 46% of the organizations have moderate to significant impact on the profitability aspect as a result of operating at different production volumes.
- More than half of the respondent organizations have a capacity to handle the varied output volumes for the different products largely.
- Technology investment in manufacturing infrastructure, explicitly the use of soft, administrative and intermediate technologies have resulted in strengthening the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly and profitably.
- Supplier involvement in modifying products has a significantly positive impact in managing the frequent volume fluctuations without sacrificing the quality of the different products.
- Supplier ability to respond to order delivery changes has a positive relationship with volume flexibility.

Modification flexibility

- The current status of modification flexibility for the manufacturing organizations is reasonably good with an average score of 0.74 and standard deviation of 0.10 only.
- 81% of the organizations strongly agree that they are capable of producing minor alterations in product design to meet customization.
- The cost of the modified or new product and transition penalties in cost has been an area of concern for the organizations.

- Only 45% of the organizations have a moderate agreement to modify the product or product mix in a short span of time.
- 55% of the organizations have the ability to introduce a large number of new or modified parts and products frequently.
- The role of supplier involvement in modifying products, explicitly the supplier assistance in minor product and process design changes and supplier involvement in managing the rapid changes in product variety have resulted in strengthening the organization capabilities to manage the achievement and development of modification flexibility.
- The strategic use of organizational infrastructural resources has shown some positive trends towards the attainment of modification flexibility.

Delivery flexibility

- The current status of delivery flexibility for the manufacturing organizations is good with an average score of 0.714 and standard deviation of 0.13.
- 62% organizations agree that they can handle rapid delivery of innovative products but 47% shows their divergence to provide delivery differentiation profitably.
- About 32% of the respondent organizations have shown their neutral response to the different measures of delivery flexibility.
- Around 50% of the organizations have a moderate capacity to rapidly introduce the customized products for new market creation.
- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization.
- The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility.
- Supplier involvement in managing minor product and process changes for an organization played an imperative role as a prerequisite in developing delivery flexibility.
- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization.
- A sourcing strategy for enhancing modification flexibility may have to be implemented in advance of similar actions to support the development of delivery flexibility.

4.15.2 Learning Issues based on Empirical Analysis

Concerning correlation analyses

- Delivery flexibility has a strong and significant association with other dependent variables i.e. volume flexibility ($r = 0.671$, $p = 0.000$) and modification flexibility ($r = 0.706$, $p = 0.000$).
- Volume flexibility has been found to have a strong positive association with the supplier involvement in volume changes requests, SIVCR($r = 0.464$, $p = 0.000$), supplier involvement in modifying products,SIMP($r = 0.483$, $p = 0.000$) and technology investment in manufacturing infrastructure, TIMS ($r = 0.532$, $p = 0.000$).
- Further, modification flexibility has established a significant positive association with SIVCR ($r = 0.479$, $p=0.000$) and SIMP ($r = 0.435$, $p=0.01$).
- Supplier competencies,SCOMP($r = 0.550$, $p=0.000$), SIVCR ($r = 0.468$, $p=0.000$) and SIMP ($r = 0.451$, $p=0.000$) has been found to be significantly associated with the delivery flexibility.

Concerning canonical correlation analyses

- SIMP has the highest cross-loading (0.511) among the independent variates for the set of dependent variates consisting of volume and delivery flexibility.
- SCOMP has come out to be second most significant factor affecting volume and delivery flexibility with cross loading of 0.503 and has the highest cross-loading (0.535) among the independent variates for the set of dependent variate consisting of modification and delivery flexibility.
- TMSYS and TIMS has a cross loadings of 0.334 and 0.338 respectively with a set of dependent variates consisting of modification and delivery flexibility.

Concerning multiple regression analyses

- TIMS and SIMP has been found to be significant for achieving volume flexibility.
- SIMP has found to be significant for achieving modification flexibility.
- The result of multiple regression indicates the positive significance of SCOMP and SIMP in achieving delivery flexibility.

4.16 Concluding Remarks

The outcomes of the survey have been studied in detail through descriptive and empirical analysis. The descriptive analysis assessed the present status of various research parameters in the manufacturing organizations. The empirical analyses have been carried out to find the association of various variables with the different manufacturing flexibilities. The canonical correlations have been used to investigate the relationship between a set of multiple dependent and set of multiple independent variables. For the closer examination of relationship between individual dimensions of dependent variables with the independent variables, the multiple regression analysis have been done using enter/step wise methods. The learning's from the survey have been summarized for further use in qualitative modeling. In the next chapter the case studies have been described with the objective of validation of survey based research results.

CHAPTER V

CASE STUDIES

5.1 Introduction

This chapter describes the detailed case studies carried out in various manufacturing organizations, which are actors in this context. The case studies have been conducted in a phased manner starting from the evolution of the need for incorporating the manufacturing flexibility at the tactical level to the excellence at the strategic level by incorporating the new technology and sourcing practices as a competitive tool in different manufacturing enterprises. In each case study, the methods/techniques/approaches adopted for achieving manufacturing flexibilities, the success achieved, the modifications made in the future plans has been compiled and analyzed in detail. The analyzed result of the case studies depicts the total industrial scenario about the perceived and achieved level of manufacturing flexibilities and assesses the relative impact of sourcing practices and new technology on different flexibilities for providing a basis for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

Furthermore, the role of cross-functional teams, value analysis techniques, effect of competitors' strategies and environmental factors for achieving manufacturing flexibilities has been collected and analyzed through case studies. The preliminary information provided by the survey has been validated by these case studies and the synthesis of the two will provide the required results.

To carry out case studies, the basis for selection of organizations has been already discussed and presented in Chapter III, Design of Study. Accordingly, the case studies have been conducted at:

- Maruti Suzuki India Limited (MSIL), Gurgaon
- Sona Koyo Steering Systems Limited (SKSSL), Gurgaon
- Moserbaer India Limited (Moser Baer), Noida
- Punjab Tractors Limited (PTL), Mohali.

5.2 Maruti Suzuki India Limited (MSIL)

Maruti Suzuki India limited (MSIL, formerly Maruti Udyog Limited), a subsidiary of Suzuki Motor Corporation of Japan, is India's largest passenger car company, accounting for over 55.4 percent of the domestic car market. Since inception, the company has produced and sold over 7.5 million vehicles, including almost 500,000 units in Europe and other export markets. The company presently has a wide product range of 11 models with around 100 variants in the market. MSIL has been a fast growing company and over the years has expanded its product range to suit a large spectrum of customers in and outside India.

Maruti Udyog Limited (MUL) was born as a government company, with Suzuki as a minor partner, to make a people's car for middle class India. Maruti Udyog Limited was incorporated in such a scenario as a fully owned Government company on February 24, 1981 with a resolve to bring about expansion and technological modernization, of the automobile sector. MUL, when started was entrusted with the task of achieving the policy objectives of modernization of Indian automobile industry, production of vehicles in large volumes, which was necessary for economic growth, and production of fuel-efficient vehicles to conserve scarce resources. To achieve these objectives, one of the foremost tasks before Maruti Udyog Limited was to determine the most suitable product mix and to select the most suitable foreign partner who would be willing to accept MUL's requirements in terms of product mix, technology transfer, and equity participation and had the required technological expertise and experience in producing high quality, reliable and fuel efficient vehicles. After extensive discussions with several major European and Japanese car manufacturers, MUL chose Suzuki Motor Corporation (SMC) of Japan as its partner in Oct, 1982, by which SMC acquired 26% share of the equity with an option to increase it to 40%. Suzuki Motor Corporation (SMC) further increased its equity holding to 50% in the year 1992, converting Maruti Udyog Ltd., into a Non-Government company with a total equity base of Rs.1322.92 million. SMC currently holds 54.2% stake in the company. Suzuki provided access to some of its products, licenses its technology, shared its best practices in manufacturing processes and helped to develop and manage the supply chain. The range of models delivered by the maruti are categorized into segment A1 (Maruti 800), A2 (Alto, Estilo, Wagon R, Swift), A3 (Sx4, Dzire), C (Omni, Versa) and MUV (Grand Vitara, Gypsy).

The company has two manufacturing facilities in India, one in Gurgaon and the other in Manesar, North India. Gurgoan facility houses three fully integrated plants. While the three plants have a total installed capacity of 350,000 cars per year, several productivity improvements or shop floor kaizens over the years have enabled the company to manufacture nearly 650,000 cars per year at the Gurgaon facilities. The entire facility is equipped with more than 150 robots, out of which 71 have been developed in-house.

Manesar facility has been made to suit Suzuki Motor Corporation (SMC) and Maruti Suzuki India Limited's (MSIL) global ambitions. The plant has several in-built systems and mechanisms to ensure that cars being manufactured here are of good quality. There is a high degree of automation and robotic control in the press shop, weld shop and paint shop to carry on manufacturing work with acute precision and high quality. In particular, areas where manual operations are hazardous or unsafe have been equipped with robots. The plant is designed to be flexible: diverse car models can be made here conveniently owing to automatic tool changers, centralized weld control system and numerical control machines that ensure high quality. The plant at Manesar is the company's fourth car assembly plant and has started with an initial capacity of 100,000 cars per year and will be scaled up to 300,000 cars per year in near future. A total investment of Rs. 2,500 crore will be made in this car plant by 2010.

Company diesel engine plant, Suzuki Powertrain India Limited at Manesar is Suzuki & Maruti's first and perhaps the only plant designed to produce world class diesel engine and transmissions for cars. The plant is under a joint venture company, called Suzuki Powertrain India Limited (SPIL) in which SMC holds 70 per cent equity with the rest held by MSIL. This facility has an initial capacity to manufacture 100,000 diesel engines a year. This will be scaled up to 300,000 engines per year by 2010. This facility, too, has a high level of automation. Final inspection of components is done through automatic measuring and marking machines, which leads to a uniform and error free production. In addition, the Manesar campus would also have, for the first time in the Indian automobile industry, a Suppliers' Park.

5.2.1 Business Initiatives and Company Strategy

The company business relies substantially on their partners and depends on a national network of suppliers, sales outlets and workshops, managed by independent entrepreneurs, to manufacture car components and look after their customers. Nearly 75,000 people are employed directly by the company and its partners. The company set up a network of component vendors, dealers and service stations and facilitated around 60 technical collaborations for Indian vendors from Japanese, European and even American partners to upgrade technology and quality levels. The company has 15 joint venture companies for component supply. Along with this came the task of instituting quality processes and systems across this network. Today, the suppliers to Maruti are huge corporations themselves and are today in the global business arena. Through the years, Maruti brought in relevant products to the market even before the market demands were visible. Maruti Suzuki India Ltd. is also the only car manufacturing company in the world to lead its home market in terms of both market share and customer satisfaction.

The snapshot of the achieved milestone and the business strategy decisions are delineated and presented in the Table 5.1.

Table 5.1 Milestones of Maruti Suzuki India Limited (MSIL)

Year	Milestones of the Company
1983	• Started production in a plant with installed capacity to produce 20,000 vehicles per annum. • Launched Maruti 800. • 1st vehicle produced in December 1983.
1984	• Installed capacity reached 40,000 units. • Launched Omni.
1985	• Launched Gypsy. • Technology adaptation for production of MUV's.
1986	• Produced 100,000 vehicles since commencement of production. • Increased plant capacity by robots and automation so as to reduce cycle time. • Developed vendors by setting Joint Vendors meant for exclusive supply to MUL.
1987	• Exported first lot of 500 cars to Hungary. • Technology development for low cost Indian alternatives for imported spares.
1988	• Reached an installed capacity of 100,000 units. • Enlarged dealers network for quick delivery to customers. • Developed vendors locally for prompt supply of material and components.
1990	• Launched sedan Maruti 1000. • 5,00,000th vehicle produced in June 1990.
1991	• Reached cumulative indigenization 65% for all vehicles produced. • Capacity augmented to 130,000 vehicles per annum.
1992	• Suzuki increased its stake in Maruti to 50%.
1993	• Launched Zen. • Technology adaptation for expansion into mid segment.
1994	• Launched Esteem. • Produced 1 million vehicles since the commencement of production. • Setting up of second plant to enhance capacity with more automation.

1995	• Plant 2 became operational. Installed capacity increased to 200,000 units. • Technology transfer and adaptation for new variants with aesthetical improvement.
1996	• Awarded star trading house status by Ministry of Commerce. • Launched 24-hour emergency on road vehicle service. • 15,00,000th vehicle produced in October 1996.
1997	• Produced the 2 millionth vehicle since the commencement of production.
1998	• CII-EXIM Business Excellence Award. • Launched website as part of CRM initiatives. • Adaptation of new technology for diesel vehicles.
1999	• Plant 3 and new press, paint and assembly shops became operational & installed capacity rose to 350,000 units. • Increased capacity of a plant by addition of new technology machines. • Launched Maruti Service Masters (MSM) as model workshop. • Launched Baleno and Wagon R. • Awarded Export excellence Award for export performance. • 25,00,000th vehicle produced in March 1999. • Gave large volume to less number of suppliers, and demanded annual price reduction/unit in lieu.
2000	• Company reported a Loss of Rs. 269 crores. • JD power customer satisfaction award given. • ITDR launched jointly with Delhi government to promote safe driving habits. • Implementation of online ERP and JIT systems between vendors, MUL and SMC for suggestions of cost saving in the components. • Maruti Alto launched. • Produced the 3 millionth vehicle since commencement of production.
2001	• Turn over with profits Rs. 104.5 crores. • Maruti Versa launched. • 35,00,000th vehicle produced in June 2001. • Developed new technology using alternatives fuels like CNG, LPG and diesel in collaboration with vendors. • Started E-buying for competitive pricing.
2002	• Divestment- Suzuki Motors Corporation (SMC) acquires majority stake in MUL (increase of 54.2%). • Maruti Finance and Insurance Launched. • 30,00,000th vehicle produced in December 2002.
2003	• Maruti Gets listed on BSE & NSE. • IPO (Issue oversubscribed 11.2 times. • New Zen launched – first facelift by Maruti engineers. • Production of 4 millionth vehicle.
2004	• A new Esteem launched second successive facelift by Maruti engineers. • Launched Grand Vitara XL-7.
2005	• Swift launched- first world strategic model from Suzuki motor corporation. • 50,00,000th vehicle produced in April 2005.

2006	• Launched 'Dil-Se' – a special program for Indian living abroad or NRIs to facilitate them to gift maruti cars on line to friends and relatives back at home. • Maruti launched Wagon-R duo with LPG. • Leading auto component maker from Japan, Bellsonica Corporation announced a joint venture company with MUL. Maruti has a hold a 30% stake in the venture whereas Bellsonica hasa hold 70 percent stake.
2007	• New Car plant and the diesel engine facility commence operation during 2006-07 at Manesar, Haryana. • SX4- Luxury Sedan launched. • Maruti Launched Grand Vitara. • Launched Swift Diesel, Zen Estilo, WagonR with facelift, WagonR Duo (LPG), immobilizer equipped models.
2008	• Planned to launch 'A-Star', a premium A2 segment car in Nov'08. • Aims to produce 100,000 cars of A-Star for export markets and 50,000 cars for the domestic markets to start with, and through tripartite agreement with Nissan and Suzuki under the contract manufacturing arrangement.

5.2.2 Performance Indicators

The snapshot of various performance indicators of the company and their trends has been presented in Figure 5.1.

Net Sales: The net sales of the company are showing a consistently rising trend. Net Sales was Rs. 90.8 bn in 2003-04, which was increased by 20% to Rs. 109.1 bn in 2004-05 due to high demand and low interest rates in the market. In 2005-06, it rose by 10% to Rs. 120 bn. The net sales, while continuing its rising trend, increased by 21.6% to Rs. 145.9 bn in year 2006-07 and further by 22.4% to Rs. 22.4 bn in year 2007-08.

Profit after Tax: The profit after tax (PAT) also showed a continuously increasing trend among the years of study. The PAT was Rs. 5.4 bn in year 2003-04 which significantly increased by 57.5% to Rs. 8.5 bn in year 2004-05 due to higher sales and other value analyses and value engineering techniques, which cut the input costs of the products of the company for this year. The trend of shooting up of PAT continued for the next year i.e. 2005-06 when it jumped by 39.3% to Rs. 11.9 bn. The year 2006-07 was another year of new hopes for MSIL, when its PAT increased by 31.4% to Rs. 15.6 bn. But due to severe escalation in the prices of input commodities in the year 2007-08, the PAT could increase further only by 10.8% to Rs. 17.3 bn inspite of 22.4% increase in sales.

Earnings per Share: Earnings per share for 2004-05 were at Rs. 29.55, against Rs. 18.77 in 2003-04, showing a marvelous rise of 57.4%. Earnings per share for 2005-06 were at Rs. 41.16 showing another impressive growth of 39.3% over the previous year. Further, following the trend of PAT, earnings per share for 2006-07 increased by 31.3% to Rs.

54.00 and for year 2007-08, it could increase by merely 10.8% to Rs. 59.9 due to increase in commodity prices during the year.

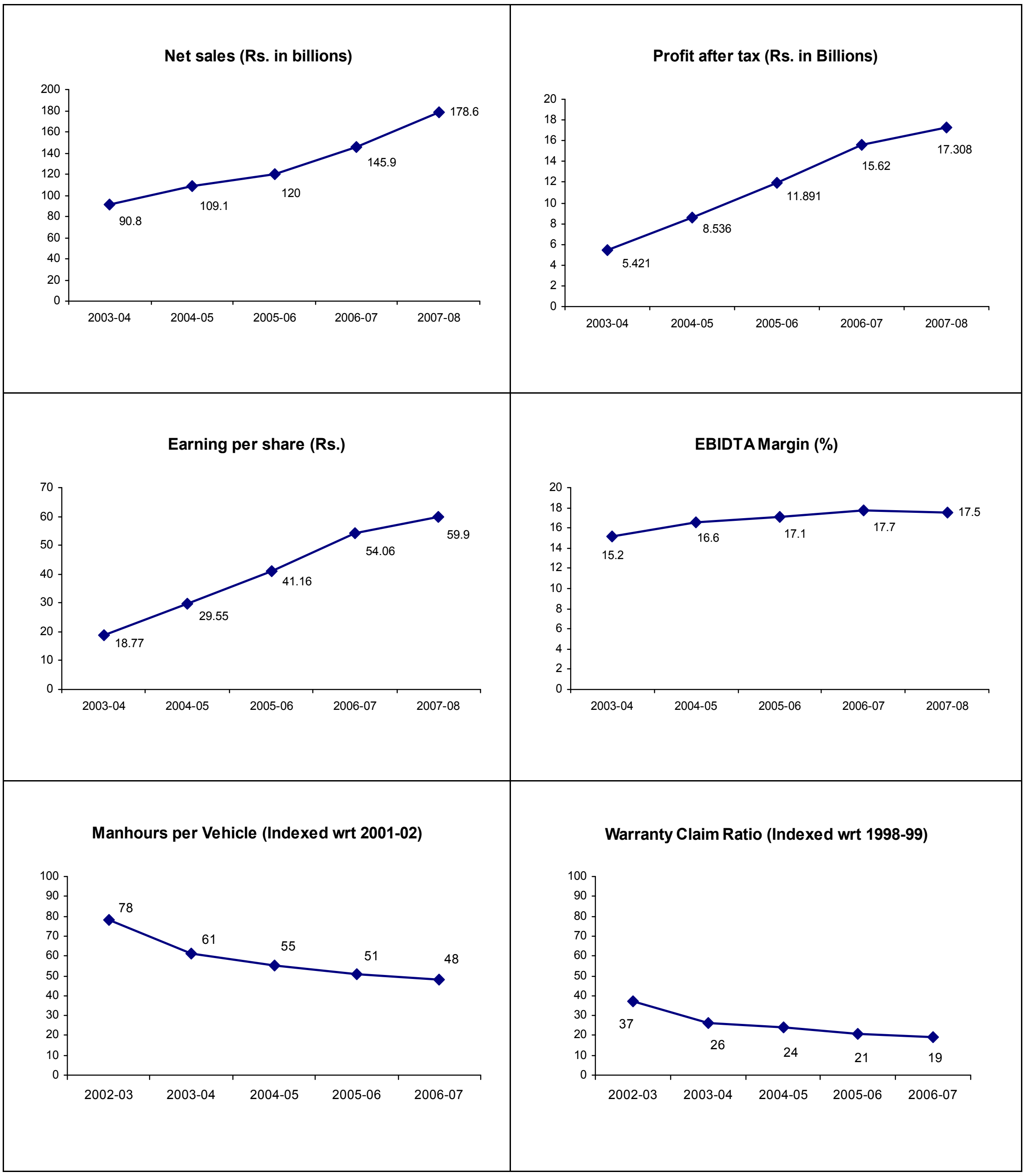


Figure 5.1 Performance indicators of MSIL

EBITDA: EBITDA margin was recorded to be 15.2% for the year 2003-04. It increased to 16.6% for the year 2004-05, then to 17.1% in year 2005-06. Following the same trend, EBITDA margin, it worked out to be 17.7% for the year 2006-07 but it marginally dipped to 17.5% for year 2007-08 because of rising costs of inputs.

Man-hours per Vehicle: The man-hours per vehicle (an inverse indicator of productivity) are showing a continuous falling trend thus representing an increase in productivity. When man-hours per vehicle indexed to 100 for the year 2001-02, its value worked out to be 78 for the year 2002-03, which fell to 61 in year 2003-04. It further fell to 55 in 2004-05, 51 in 2005-06 and then 48 in year 2006-07. This rise in productivity has been possible partially due to the adoption of Production Management System by the company in collaboration with shop floor employees.

Warranty Claim Ratio: The Warranty Claim Ratio (an inverse indicator of quality) is also showing a continuous falling trend, thus depicting a continuous rise in quality of products. When warranty claim ration indexed to 100 in year 1998-99, its value was merely 37 in year 2002-03 which reduced to 26 in year 2003-04. It further reduced to 24 in year 2004-05, 21 in 2005-06 and 19 in 2006-07. This indicated that the company is constantly upgrading its manufacturing processes and taking a series of initiatives to ensure consistency in product quality.

5.2.3 Manufacturing Capacities and Capabilities

The company has build capacities, capability and management bandwidth through the value chain in the recent years. This has been evident in the continued expansion of the company's sales and service network, and the growth in manpower in the field. Further, there have been efforts to enhance design and development capabilities within the company and among suppliers. The diesel power train plant at Manesar is a state-of-the-art facility and Suzuki's first diesel venture meant to feed its global operations from India.

Productivity: Improving productivity is an ongoing effort at Maruti, through the Maruti Production System, or MPS, which is derived from the Suzuki Production System, and focuses on elimination of wasteful activities taking place during manufacturing processes. In addition to MPS activities, in-house automation, increasing utilization of production lines, outsourcing of low value-addition jobs and reduction in materials handling have contributed to improvements in the productivity of their employees and the efficiency of operations.

As a result, at Gurgoan facilities, where installed capacity is 350,000 cars per year, the company was able to make nearly 650,000 cars in year 2007. Many of these good practices have been transferred to key suppliers, which has improved productivity and reduced cost across the value chain.

Quality: The company has constantly upgraded its manufacturing processes and taken a series of initiatives to ensure consistency in product quality. The quality assurance team works closely with the large base of suppliers through regular guidance and well-defined programs. Maruti is upgrading manufacturing processes and quality systems of its direct suppliers as well as tier-2 suppliers. As a result, the company was able to reduce overall warranty claim ratio by more than 3% in 2006-07 over the previous year, and by more than 37% over the last four years.

Many suppliers are involved in the design and development of components of new models, along the company's engineers. This has helped the company in launching world class, high technology new models such as Swift, Zen Estilo and SX4, with very high levels of localization and matching international quality standards. Maruti models, Zen and Swift were ranked first in their respective categories in the Initial Quality Study conducted by JD Power Asia Pacific. In another customer survey conducted by TNS, Esteem, Swift, Zen and Maruti 800 achieved the top position in their categories.

Cost: With increased competition, stringent automotive regulations and increased customer expectations, there a likelihood of increase in costs, putting pressure on margins of the company. Increase in commodity prices puts further pressure. For existing products, a focused "cost down" strategy has been adopted. This involves jointly setting up challenging cost reduction targets for specific existing models. Thereafter, the company and suppliers jointly generate value analysis ideas and implement them within the stipulated time. A dedicated arm, Maruti Centre for Excellence, which imparts training to suppliers and helps them upgrade quality, productivity and operational efficiencies, supports these efforts.

5.2.4 Role of Technology

The engineering and technology area of the company has progressed from the introduction of special editions, upgrades and new variants, to establishing the capability for facelift of models, to designing contemporary world cars such as Swift and Zen Estilo, jointly with engineers at Suzuki Motor Corporation (SMC). MSIL is gradually shaping up to become the design hub of SMC for its Asian operations outside Japan. In the recent past, Maruti has increasingly been recognized for offering cars with contemporary style and design, with the latest features and technology, and at prices far more aggressive than competitors. The shift in image began with the Swift (Petrol) in 2005, and a new profile of customers who have earlier migrated to competition owing to conventional design, returned to Maruti. The Zen Estilo, new WagonR, Swift Diesel and lately, SX4 and Grand Vitara reinforced this trend. It is believed that while retaining its traditional values of low cost of ownership, reliability and performance, Maruti has been able to change its image to appeal to the rapidly growing segment of young Indian customers. Growing design capability in the area of cars, components and dies, both within the company and among suppliers, has fostered this "target cost" approach.

Besides, cost have come down owing to consolidation of suppliers, improved productivity, economies of scale, focused Value Analysis and Value Engineering efforts, leaner operations and tight inventory control have contributed to lower costs at suppliers' end. The net impact of all these efforts in operations is that many of the models like Alto, Esteem and Maruti 800 cost less today, even in nominal terms, than they did in 2001-02. While being superior in terms of Bharat Stage III technology and more features, they cost less now providing a strong competitive edge to Maruti. Further, these efforts improve the organization responsiveness to the market environment fluctuations and promote the manufacturing flexibility.

Product Development: The product development cycle at Maruti Suzuki has been considerably shortened to respond to market conditions. The recent past have seen the launch of five models, which is very new in the auto industry. Company was also able to improve existing models and offer many variants in each category. All aspects including facility planning and capacity building is looked into and an efficiency improvement method at each level is implemented. Cost reduction is looked into at every stage. Other technical aides like the Digital Mockup and Ergonomics Simulation help check every aspect at the design level itself. Ergonomics Simulation helps in checking the new product design even before the development is done. This translates into savings in terms of time and cost. All other aspects like tools usage / assembly feasibility is done using digital mockup.

New Technology - Adoption, Adaptation and Innovation: The company is working towards localization, development and testing of products - both new and existing. This helps in indigenization of various vehicles aggregating to lower the costs. The launch of Zen Estilo, launched with a localization of 94.2% is a case in point. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization are further improving and upgrading existing models for comfort, style and value for money. Alternative fuels like CNG, LPG, which help in making environmentally friendly vehicles, are being worked upon. Global sourcing and advanced sourcing get advanced technologies into India at lower costs.

Efforts made towards technology absorption, adaptation, innovation and R & D along with the benefits derived and future plan of action has been presented in the Table 5.2.

Table 5.2 Role of technology, innovation and R&D at MSIL

EFFORTS MADE TOWARDS TECHNOLOGY ADOPTION, ADAPTATION AND INNOVATION AND R & D	BENEFITS DERIVED AND FUTURE PLAN OF ACTION
Towards technology adoption, adaptation and innovation • Localization development and testing of parts for existing and new models. • Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization. • Capabilities being further strengthened in areas of alternative fuels like Diesel, CNG and LPG. • VA/VE at the time of design and localization to maximize cost benefit. • Acquiring design and cost knowledge through teardown and benchmarking. • Global sourcing to get advanced technologies into India at lower costs.	**Benefits due to technology adoption, adaptation and innovation** • Indigenization of various vehicle aggregates at lower costs. • Improvement and up gradation of existing models for new market creation. • Continuous reduction in product cost through VA/VE. • Increased product and process flexibility. • Significant cost reduction of new model parts compared to existing models, ensuring that the new models are profitable from day one. • The efforts to launch new models with high localization resulted in Zen Estilo being launched with a localization of 94.2%. • Significant cost reduction obtained in existing models.
Specific Areas in which the company has carried out R&D in the recent past. ***a) Building Full Model Change Capability.*** • Strengthening of facility and skill enhancement in styling concept generation, model making and designing including Class A surfaces. • Design development capability for front and rear facia, front and rear underbody, instrument panel and backdoor. • Hi Localization and development of components for new and existing models. • Structural vibration analysis. • PLM to manage CAD, CAM and CAE data for in-house and also to collaborate with SMC and suppliers. • Virtual vehicle testing for strength, durability and safety. ***b) Design capability for components/ systems for VA/VE.*** ***c) Alternate Fuel LPG: Development of LPG system for MPI engine.*** ***d) Compliance to Bharat Stage III Emission norm & other regulations.***	**Benefits derived as a result of R & D** • Launch of Swift Diesel, Zen Estilo, WagonR with facelift, WagonR Duo (LPG) and Alto X fun. • Launch of immobilizer equipped models. • Launch of Alto 800 LHD and Zen Estilo in overseas market. **Future Plan of Action** • To upgrade R & D capabilities for total evaluation of products. • To develop capability for full model change. • Emphasis on VA/VE to cut down costs. • Carry out continuous up gradation of existing models. • Maximum localization for achieving cost reduction in existing as well as new models. • Compliance to Bharat Stage IV emission norms and other new regulations. • Developing Costing Knowledge of various Automotive Technologies through standard cost tables and cost benchmarking. • Finalization of target cost at the time of planning of new product to put cost in right perspective at the conceptual stage.

R&D activities of Maruti have the twin objectives of reducing product costs by developing capabilities of local vendors and becoming a regional R&D hub for all Suzuki operations. The company has adopted a 'focused model cost reduction' technique. Maruti has been continuously engaging in Value Analysis/Value Engineering (VA/VE) activities across its operations. Some areas in which MUL carry out research and development are localization and development of components, cost reduction measures such as VA/VE, development of alternate fuel (CNG and LPG) vehicles, performance-benchmarking to certain parameters such as noise, ride handling and braking and development of power-steering for certain models. MSIL regularly upgrade its models and also launch variants by adding features developed through research and development.

Digital Manufacturing: The company is using digital manufacturing to bring out cars at rapid pace and has introduced five new models, Wagon R-LPG, Zen Estilo, Swift Diesel, SX4 and Grand Vitara launched in less than two years. The model introduction time has now reduced by 25 per cent. Merits of digital manufacturing includes the reduction in time-to-market by shortening lead-time, reducing costs of the manufacturing planning processes as well as product development in general by streamlining production planning and assessing production feasibility of a model by simulating manufacturing operations before the beginning of production. Another benefits include the reduction in the number of prototypes by using digital mockup (digital manufacturing) and line simulations and improving collaboration, both internally and with suppliers, by providing early access to design, process, and resource information in a controlled environment.

Adoption of Information Technology: One main pillar of the lean and efficient business operations of the company is effective IT enabling of all business processes. Information Technology (IT) applications such as Enterprise Resource Planning (ERP) systems, Supply Chain Management (SCM) systems can support lean philosophies, which provide an opportunity for auto component manufacturers to gain considerable competitive advantage through increased productivity; improved quality and shorter production lead times. These packages are designed to support manufacturers' requirements to produce customized products with short lead times at production costs that reflect the efficiencies typical of mass production operations. Today, IT embraces all critical processes including product development and manufacturing and is a crucial tool in the operations. Broadly, IT has strengthened the organization capabilities in the following four areas;

i. It has helped to keep low inventory-a pre-requisite for 'Lean Manufacturing'.
ii. It has given the flexibility to manufacture 11 different models with over 100 variants.
iii. It has enabled to service the customers better by ensuring smooth flow of cars and spares across a national sales and distribution network.

iv. And finally has helped in many ways to improve customer interface.

At least 18,000 consignments from different suppliers reach MSIL everyday and still the average domestic inventory is restricted to about 2 hours. Cars worth Rs. 550-660 million are sold every day, all on a click of the mouse. The entire production line is IT enabled and quality is maintained at a consistent level because of the use of Information Technology including ERP systems. The company has further strengthened the integration of IT and production system by introducing a first of its kind solution, using Radio Frequency Identification (RFID) technology.

IT not only helps in the day to day maintenance and progress of work, it also helps in adding many advantages to the system that could translate into benefits to the consumer. The Production and communication between demand and supply is set to clockwork and this is only possible because of the extensive use of technology. The company has taken a series of initiatives for IT implementation at plant and vendors end to enhance the level of business performance parameters including productivity, flexibility, cost savings and improved working of dealerships by empowering them with valuable data and systematically presented in the Table 5.3.

Table 5.3 Implementing information technology at MSIL

Categorization of IT Sytem	**Implementation Process**
E Sourcing	Maruti has an in-house E Sourcing office dedicated for purchasing goods and services online. E-sourcing facilities including ERP systems have been extended to vendors, which help them procure goods and services faster and cheaper through auction.
Delivery Instruction System	One of the best practices inherited from parent company Suzuki in the form of Delivery Instruction System for material scheduling and ordering is called 'E-Nagare'. It helps in maintaining 'Zero or Lean Inventory'. E- Nagare ensures that supply schedule is generated and communicated electronically and automatically to all vendors every day for next day's supplies. To regulate this vendors are given orders every two hours for supplies throughout the day. Supply timings are spaced out equally to maintain uniform flow.
Warehouse Management System (WMS)	Managing inventory of spares can be taxing in absence of accurate IT solution. To simplify this exercise Warehouse Management System (WMS) was developed which could facilitate increased inventory turnover and faster turnaround time. SMC (Suzuki Motor Corporation) Indonesia adopted this IT solution.
Vehicle Tracking System (VTS)	Vehicle Tracking System (VTS) between business systems and shop floor systems enhances the shop-floors efficiencies by providing correct and timely instructions to shop floor along with feedback to the business systems. Loss of valuable data or pilferage of any sorts posed an important challenge. Information Security by defining a comprehensive security policy helped attain BS7799 Security Certification.

Dealer Management System	The newly implemented Dealer Management System (DMS) has improved working of dealerships by empowering them with valuable data. DMS is a centrally hosted system, which connects dealers' spread all over the country providing them important information on business operations. The system empowers the dealers by placing valuable data at their fingertips. The data in turn assists in decision-making at the highest level, helping Maruti improve its interface with the end customer.
Employees Connect	Keeping employees connected is another dimension, which is well addressed by ERP (Enterprise Resource Planning and Oasis Portal-Information Portal. This online processing system has brought all business processes within a single network such that employees can service themselves online for their needs. Employee's services vary from taking online leave applications, to salary details, procurement of goods and services so on and so forth.

5.2.5 Role of Sourcing Practices

MSIL's inputs primarily comprise raw materials and purchased components. Only a small amount of raw material and components consumed are imported and a much larger portion is purchased from the sources within India. The localization levels are as high as 90 per cent. Company supplier partners have been major contributors to its turnaround. Less than 20 per cent of a car is manufactured in-house. MSIL has a strong base of around 215 suppliers and hundreds of second and third tier of suppliers who, in turn, supply to them account for the rest.

Raw Material Suppliers: The raw materials used in the manufacturing process primarily comprise steel coils and paints. In recent years, company is increasingly trying to localize the purchases of steel coils with a view to reduce cost. At MSIL the role of the suppliers has gradually evolved from tactical to strategic where the suppliers work in close coordination with company to meet company long-term goals in terms of component development, quality, delivery and cost control. In order to improve quality and generate economies of scale, MSIL has reduced the number of suppliers of components in India. In case of repair and replacements, costs of defective components supplied are borne by the supplier.

Delivery by Suppliers: MSIL has a delivery instruction system that provides details of the component requirements, across the different variants of the various models, to the suppliers. Suppliers are linked to the company through the Internet-based information network, which maintains online information regarding order status and delivery instructions. These has helped in reducing both inventory levels and lead times required for the supply of various components and sub-assemblies, and enable the suppliers to more efficiently plan and dispatch their products. Suppliers located within a radius of 100 kilometers from the manufacturing facility supply the majority of the components. This has enabled the suppliers to eliminate packaging and supply components directly to the assembly line.

Reduction of Supplier Costs: In some of the major suppliers MSIL has implemented the MPS, which focuses on the elimination of wasteful activities in their manufacturing processes. Suppliers are helped in areas such as improving their productivity, reducing the number of their components that are rejected, reducing materials handling, improving their yield from materials, and reducing their inventories. This helps reduce their costs of production, and also reduces the costs of the components required. In addition the work is going on to integrate the suppliers into the worldwide purchase system, or WWP, whereby a supplier may become the sole supplier for a Suzuki product in several countries including India. This would generate economies of scale for the supplier and result in the reduction of the costs.

Supplier Quality Control: Quality management system such as ISO 9000/ QS 9000 forms the basis for producing a quality product. To assist small and medium suppliers in achieving ISO 9000 certification, in 1995 MUL adopted a cluster approach wherein suppliers are grouped together, are trained in quality management and are assisted in obtaining ISO 9000 certification. This cluster approach was extended to helping suppliers attain QS 9000 certification. Periodic supplier quality system audits are conduct in order to ensure that quality standards are sustained.

Strengthening Supply Chain: For attaining the million mark, Maruti Suzuki is aggressively working on different facets of the supply chain. The company is rapidly moving from 'Domestic Leader' stature to 'Global Leader' stature by adopting global practices.

- Transition from Component supplier to System Supplier.
- Raising the quality and responsibility benchmarks for Tier-I or primary suppliers.
- As number of system suppliers increases the model launch time reduces.

Involving Suppliers at Development Stage: Another interesting initiative is the early involvement of suppliers. It triggers innovations at the designing stage itself. Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage. Perhaps that is reason why company models now are launched with as high as 90 per cent levels of localization.

Move to upgrade Suppliers to World-Class Levels: In collaboration with the suppliers the company has set up Maruti Centre for Excellence (MACE) to provide consultancy and training support to suppliers and sales network to enable them to achieve world-class standards in Quality, Cost, Service and Technology Orientation. MACE works closely with the partners to implement world-class practices like TQM, TPM and TOPS (Team Oriented Problem Solving techniques). MACE was established to train Tier-II and Tier-III suppliers (term used to describe suppliers of company component supplier who are Maruti's indirect supplier). Component development capabilities of the suppliers have been upgraded through MACE and are helping us develop new models with shorter lead-time and enabling company to innovate successfully in new tools and fixtures with local expertise. In addition, the Centre also trains Maruti employees in Quality related issues.

5.2.6 Social and Environment Aspects

The company has successfully launched various schemes for its employees and customers as an endeavor to fulfill its social responsibilities. Motivating and retaining good people, recruiting a large number of people with the right competencies, integrating new entrants quickly with the corporate culture and values, getting them to become productive quickly and developing them for the future are key focus areas for top management in Maruti. Another intangible but significant organization-wide change was the start of a culture of celebrating success. Celebrating success together creates a strong bond, enthusiasm and pride, thus enhancing team building andindividual performance. The relationship with all employees has been cordial throughout. The attrition rate in the category of executives and above came down from 11.8% in 2004-05 to 10.5% in 2005-06.

The company, along with two suppliers, had adopted four Industrial Training Institutes (ITI). Maruti Driving Schools (MDS), an initiative that had started with three pilot schools in March 2005, has gained momentum. The company has, in partnership with dealers, activated 21 such driving schools across the country and trained over 7700 people, over 50% of them women.

The company has continued its thrust towards energy conservation and compliance of environmental regulations to meet and improve targets. As a result of good environmental performance, the plant had a successful ISO-14001 surveillance audit by AV Belgium in year 2007 for the next 3 years. The major initiatives has been taken during the recent past for reducing energy consumption (electricity, air, gas and water) and includes increased use of energy efficient lighting (e.g.: Electronic ballast, CFLs, T-5 lights), new energy management software for compressed air plant, improvement in overall efficiency of plant by increased use of waste heat through maximizing running of steam driven compressor by installing steam condenser and training programs to improve the awareness on energy conservation. These initiatives and other efforts have resulted in reduction of energy consumption per car by 2.5%, air by 1.8%, water by 4.0%, steam by 4.5% and gas by 2.2% during the year 2007-08.

5.2.7 SWOT (Strength, Weaknesses, Opportunity, Threat) Analysis

On the basis of the study carried out in MSIL, SWOT analysis has been done in which the strengths, weaknesses, opportunities and threats for the company has been identified. Table5.4 shows the SWOT analysis at MSIL.

Table 5.4 SWOT analysis at MSIL

Strengths	Weaknesses
• Full technological support from SMC • Japanese philosophy of manufacturing. • In house R & D center for validating the designs and developments in Indian context and reducing cost through vendor development. • High level of flexibility in products and processes. • High level of commitment from top management. • Leader in market share and customer satisfaction. • Expertise in small car technology. • High degree of automation and robotics. • Extensive product portfolio to satisfy various segments of customers. • Extensive sales and service network • Integrated manufacturing facility. • Strong vendor base and higher rates of localization. • Phased transformation of component suppliers to system suppliers.	• A few costly imported component of the vehicles. • Indian road conditions not favorable in rural areas. • Rules and regulation related to tax structure not favorable. • A big unorganized sector producing non-genuine spares parts for Maruti vehicles • Lack of experience in diesel engine technology. • Manufacturing facilities located focused in and around Gurgaon, adds significantly to transportation cost for sale in southern states.
Opportunities	**Threat**
• Rising demand of personal vehicles in India. • Increasing standard of living of the middle class families. • Availability of risk taking vendors, suppliers, dealers and service. • Export avenues in the neighboring countries. • Developing new vehicles using alternative fuel such as CNG, LPG, etc. • Potential business by "True Value" program	• Growing competition in the market after entry of many MNC in car industry. • Reducing profit margins due to increased competition. • Accumulation of inventory as a result of market conditions, transport and others. • Increasing prices of petrol reserves in the world. • Excessive dependence on the local vendors

dealing with preowned cars. • Growing need of fleet for corporate houses through N2N fleet management program. • New avenues with Maruti finance and Maruti insurance. • Wide business opportunity through Maruti Genuine Spares and Maruti Genuine Accessories • Focused marketing efforts. • Easy availability of finance for customers. • Extensive use of VA/VE to reduce cost, improvements in yield, productivity and quality.	for component supplies. • Movements in commodity prices related to ferro alloys, non-ferro alloys, plastics, rubber and precious metals. • Retaining the trained manpower as a challenge for the company. • For proprietary technology, company is dependent solely on a single source, which can lead to disruptions in production. • Commodity price risks. • Exchange rate risks.

5.2.8 Status of Manufacturing Flexibility

The company is capable of introducing the process improvements, produce large number of product categories and manage volume changes quickly. The manufacturing system can be expanded easily when needed in the long run without affecting the quality levels of output. The company quickly and efficiently handles the different delivery sequences and changeover to different product mix. Product configuration can be changed many times during the manufacturing process to accommodate customer preferences. Manufacturing system of the company has a capacity to put new product design into production quickly. The manufacturing flexibility at strategic level including delivery flexibility has also found to be the area of excellence.

Volume Flexibility: The company has a capacity to handle rapidly increasing and varied output production volumes for the different models and their variants. In addition, the process improvement can be introduced in the manufacturing system, without creating disturbances and maintaining the desired quality levels. However, operating at different production volumes in a manufacturing system has some impact on profitability of the company.

The company has strong and close relationship with its suppliers. Most of the non-core competency jobs which do not add to the value have been outsourced to the vendors. The company has used the concept of “compressed lines” to achieve the volume flexibility, in which non-value addition jobs are outsourced to the suppliers. The company also helped their suppliers to introduce flexible lines at their plants to manage volume flexibility. To ensure smooth and quality supply of the components, the company periodically audits the manufacturing process at supplier end. The Maruti Production System has been implemented at most of suppliers' places to control waste, maintain fast deliveries and cost reduction of the components.

The use of information and communication technologies and ERP systems including E Sourcing, Delivery Instruction System, Warehouse Management System and Vehicle Tracking System has significantly helped the company to manage the volume flexibility needs.

The company has largely invested in AMTs over a period of time to fulfill the volume flexibility needs. Further, the significant investment in the automation of material handling system and redesigning of the existing manufacturing system has been carried out. The company has competently used its assembly lines with more than 100 percent capacity using MPS and MACE. In house R&D has helped the company to indigenously develop robots. All of these efforts in course significantly help the MSIL to achieve volume flexibility.

Modification Flexibility: The company has currently a range of 11 products with 100 variants and has a past record of continually modifying the products. The company has a capacity of producing minor alterations in product design to meet customization quickly and efficiently. The company has introduced a number of modified products in the recent past. Product modifications are accomplished without incurring high transition penalties or large changes in performance outcomes. All aspects including facility planning and capacity building is looked into and efficiency improvement methods at each level are implemented. Cost reduction is looked into at every stage. Launch of Swift Diesel, Zen Estilo, WagonR with facelift, WagonR Duo (LPG) and Alto X fun are some of examples as far as modification derived in the recent past. Launch of immobilizes equipped models and Launch of Alto 800 LHD and Zen Estilo in overseas market also add to company ability to modify the product indigenously or with the vendors.

The company has developed the new technology using alternatives fuels like CNG, LPG and diesel in collaboration with suppliers leading to the introduction of modified versions of their products. The expansion of manufacturing facility with new technology has helped the company to achieve the modification flexibility. The company has invested in CNCs, Robots and Flexible Manufacturing Systems to enhance its capability to modify the products.

The technological capability of supplier(s) has assisted the company to introduce product modifications to a large extent. The suppliers are involved at the design stage to reduce the lead-time for modification and reduction in cost. Apart from technological aspects the company has modified its products from aesthetical, comfort and appeal front in association with the vendors. The role of vendors in the company is gradually shifting from component supplier to the system. Use of value analysis and value engineering, and cross functional and cross organizational teams has assisted the company to explore its own and vendors capabilities for achieving modification flexibility.

Delivery Flexibility: Delivery flexibility is the ability of manufacturing system to respond to or influence market changes and enables the rapid delivery of innovativeness, customized products for new market creation. MSIL has a capability to handle rapid delivery of innovative products and provide delivery differentiation profitably. The product configuration can be changed many times during the manufacturing process to accommodate customer preferences. Further, the customized products for new market creation are handled with ease, except the implementation of “cost target approach” that makes the process more stringent, complex and competitive in nature. The use of technological and sourcing aspects helps the company to introduce new products with minimal lead-time. The role of supplier at strategic level has largely influence the company capabilities to achieve higher level of delivery flexibility. The implementation of technology in manufacturing systems, infrastructure and design has significantly influenced the delivery flexibility.

The product development cycle at Maruti Suzuki has been considerably shortened to respond to market conditions. The last two years (2006-07) have seen the launch of five products, which is very new in the auto industry. Other technical aides like the Digital Mockup and Ergonomics Simulation help check every aspect at the design level itself. Ergonomics Simulation helps in checking the new product design even before the development is done. This translates into savings in terms of time and cost. Finalization of target cost at the time of planning of new product to put cost in right perspective at the conceptual stage. All other aspects like tools usage / assembly feasibility is done using digital mockup.

The key areas of investment will also be to develop R & D capability and infrastructure so that company can develop a full model at Maruti, and also help develop products for other Suzuki operations in Asia. In addition to the planned capital investments of Rs 9000 crores (US$ 2 billion approximately), in setting up new manufacturing and engine facilities, bringing newer models, fresh investment of US $1.8 billion have been allocated towards developing a dedicated Research & Development Centre here in India, supporting Suzuki's global ambitions. Maruti targets to make and sell a million cars in the domestic market by 2010. As announced earlier, company plan to produce another small car, a large part of which is meant for exports to European markets starting in calendar year 2008.

Another interesting initiative is the early involvement of suppliers, which triggers innovations at the designing stage itself. Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage for the related components. Perhaps that is reason why the models now are launched with as high as 90 per cent levels of localization.

Overall, the status of tactical and strategic level manufacturing flexibilities in the context of the study for MSIL has been graphically revealed in figure 5.2.

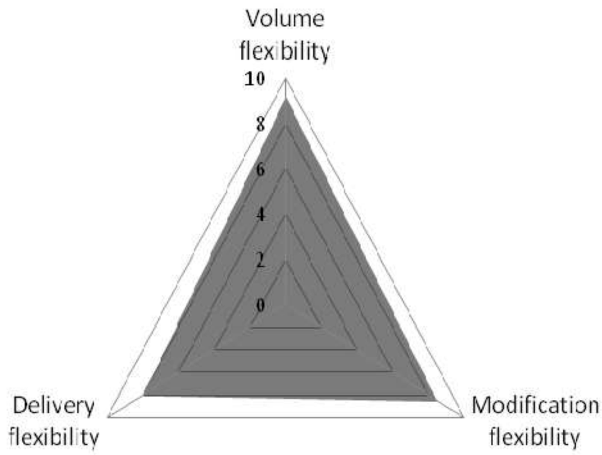


Figure 5.2 Status of manufacturing flexibility of Maruti Suzuki India Limited

5.2.9 Relative Performance of Technology and Sourcing Practices

Leadership in technology, innovation and R&D has helped the MSIL to retain and further increase its market share in the highly competitive and turbulent market environment. At the same time, the involvement of the vendors at operational, tactical and strategic level helps in pacing the rate of growth for the company. The relative impact of adopting new technology vis-à-vis sourcing practices for achievement of different business objectives has been presented in the Table 5.5.

Sourcing practices have significantly increased the delivery, flexibility and profit aspects of the company; along with moderately decrease in the product cost and cost of future product innovations. However, adoption of new technology has significant positive impact on various quality and delivery parameters. It further facilitates the company to retain its market share and adjust to market requirements.

Table 5.5 Impact of adopting new technology and sourcing practices at MSIL

		Impact of adopting new technology on performance objectives	Impact of adopting sourcing practices on performance objectives
1. PRODUCT QUALITY			
i.	Performance of products	+++++	++++
ii.	Features of products	++++	+++
2. DELIVERY			
i.	Speed of delivery	++++	+++++
ii.	Number of customized product offered	++++	++++
iii.	New product lead time	++	+++
3. FLEXIBILITY			
i.	Variety of modified products	++++	+++++
ii.	Delivery of innovative products	+++++	++++
iii.	Capacity to change product volume	++++	+++++
3. COST			
i.	Product cost	+++	++
ii.	Cost of future product innovations	+++	++
5. EFFECT ON MARKET SHARE		++++	+++
6. NET PROFIT		++++	+++++
7. OVERALL PERFORMANCE		**HIGHLY SATISFIED**	**HIGHLY SATISFIED**
(+) Significantly decreased, (++) moderately decreased, (+++) Remained the same, (++++) moderately increased, (+++++) significantly increased.			

In order to meet market requirement, the MSIL have always been adopting new technologies to keep its products abreast with those of international competitors. The company has a fully-developed set of technological capabilities and is able to help define the international technology frontier. In many areas it takes a creative and pro-active approach to exploiting technology for competitive advantage. The level of dependency on different sourcing practices and technology for achieving the different manufacturing flexibilities has been presented in Table 5.6.

The role of infrastructural technology and supplier involvement in managing capacity fluctuations has come out be important factor for achieving volume flexibility. Investment in manufacturing and design technology and supplier competencies has significantly influenced the achievement of delivery flexibility. The company has adopted ERP based systems to achieve manufacturing competitiveness and perform better in the global market.

Table 5.6 Dependency on different practices for achieving flexibility at MSIL

Sourcing Practice ⟶	**OUTSOURCING OF MANUFACTURING**	**STRATEGIC SOURCING** ***(Outsourcing the in-house core competencies)***	**ADOPTION OF NEW TECHNOLOGY**
VOLUME FLEXIBILITY	++++	++	+++ **(Main focus infrastructural technology)**
MODIFICATION FLEXIBILITY	++++	+++	++++
DELIVERY FLEXIBILITY	+++	+++ **(Component level, through Joint ventures and approved tier-1 supplier)**	++++ **(Main focus R& D, CAE)**
+ - Not dependent, ++ - Least dependent, +++ -Moderately dependent, ++++ - Highly dependent, +++++ – Fully dependent			

Supplier involvement through VA/VE and cross-functional teams are important for modification flexibility. Suppliers' technological competences, improvement in product variety and low delivery time have been the important factors to adopt different sourcing practices. Organization relies on small but high quality suppliers and strives to establish long-term relationship with suppliers. Suppliers are trained and helped to achieve various business parameters more efficiently and effectively. Early involvement of suppliers triggers innovations at the designing stage itself. This will further lead to achieve cost target approach at design stage itself.

Overall the company depending upon its key capabilities, time and type of actions and level of success in the market can be categorized as market leader.

5.2.10 SAP Analysis

Based on the business strategy and initiatives taken by the MSIL in the process of achieving the different manufacturing flexibilities, the Situation-Actor-Process (SAP) analysis has been done. Table 5.7 shows the SAP analysis at MSIL while LAP synthesis is described.

Ongoing process includes the adoption of new technology in manufacturing, design and infrastructural technologies, which further paved the way for achieving higher quality, introduction of new and modified products, minimal waste of all kinds and sustained market share in the highly turbulent and competitive market environment.

Table 5.7 SAP analysis at MSIL

<table>
<tr><th>Situation</th><th>Process</th></tr>
<tr><td>• MSIL obtained its technology from Suzuki Motors Company (SMC) of Japan.
• The company is manufacturing a large variety of cars and utility vehicles of suit various segments of the society.
• Many MNCs have entered in the Indian automobile market manufacturing vehicles employing advanced technology.
• Manufactures are offering various models/variants at competitive prices.
• MUL noticed stagnation in its market share in the recent past.
• Leadership in technology, innovation and R&D for increased localization.
• Vendor development through implementation of Maruti Production Systems and MACE.
• Total demand of cars in the market has increased.
• Production capacity of the company has increased over the years.
• Increase in purchasing power of people and availability of soft loans has made the cars within easy reach of people.
• MSIL has also built-up its diesel engine technology.
• MSIL has been striving for full indigenization of its vehicles.
• Involvement of people in management decision-making has increased in the past years.
• Government of India is taking steps to uplift the industrial growth by new economic policies.
• The role of Government in management of Maruti has ceased.</td>
<td rowspan="3">Technological Aspects
• Optimal use of local manufacturing facilities, skill and raw material through a strong base of vendors.
• Reducing the product development time through local research and development facilities.
• Getting technology up gradation by addition of automation, mechanization and robotics.
• Increasing indigenization of components for substitution of imported ones.
• Introducing new features in the vehicles as and when required.
• Developing new diesel engine technology.
• Cost reduction by reducing waste, minimizing down time and increasing OEE.
• Giving more participation to the employees by effective implementation of TPM and TQM programmes.

Sourcing Aspects
• Categorization of vendors as tier-1, tier-2 and tier-3 for vendor consolidation.
• Direct dealing of MSIL with tier-1 vendor to promote supply from single source.
• Getting a yearly price reduction of 5-10% on large quantity orders with single vendor.
• Encouraging vendors to offer suggestions for technological improvements and price reduction of the components.
• Reducing inventory levels through JIT.
• Shortening of procurement time from the vendors through on-line link.
• Getting supply from the vendors in the assembly area directly.
• Strengthening quality standard by accreditation to ISO 9001:2000, ISO 14001, QS 9000 And TS 16949.
• Increased and more effective advertisements.
• Making available Maruti Genuine Spares (MGS) and Maruti Genuine Accessories (MGA) for customer delight.
• Financing the vehicles to the customers with minimum formalities.</td></tr>
<tr><th>Actors</th></tr>
<tr><td>• Top management of the company
• Suppliers (tier-I and tier-II) to MSIL for their suggestions and participation at all levels of business operations.
• Strategic partners and dealer base of the company.
• Participation of all the employees in organizational goals.
• All the customers for their feedback and suggestions.</td></tr>
</table>

Further, the implementation of value analysis techniques, cross-functional and cross-organizational teams has strengthened the organization capabilities to curtail down the costs and improve flexibility. However, the various barriers owing to the high cost of acquisition, constrained capabilities and adaptation problems restricted the free onset of this approach.

The company has also invested largely for the growth of its strategic partners and supplier base. Through regular guidance and well-defined programs, Maruti is upgrading manufacturing processes and quality systems of its direct suppliers as well as tier-2 suppliers. As a result, the company was able to reduce overall warranty claim ratio by more than 3% in 2006-07 over the previous year, and by more than 37% over the last four years.

Maruti's healthy top-line growth, coupled with continuous improvements in operational efficiencies, has contributed to its strong financial performance with increase in net sales, operating profit margins and profit after tax. Many suppliers are involved in the design and development of components of new models, along with the company's engineers. This has helped the company in launching world class, high technology new models such as Swift, Zen Estilo and SX4, with very high levels of localization and matching international quality standards. However, the suppliers' integration in manufacturing system will also lead to organizational complicacies, loss of control and confidentiality dependency.

As a result, the adoption of new technology has significantly influenced the attainment of different manufacturing flexibilities primarily at strategic level, and followed at tactical level. The use of sourcing practices primarily impacted the achievement of manufacturing flexibility at tactical level and followed at strategic level.

5.2.11 Learning Issues

Based on the detailed study and analysis of the initiatives taken by MSIL to attain flexibility, quality, cost reduction and productivity following learning issues have emerged.

Importance of business initiatives: In a competitive market environment, where market decides the price of the product, the organizations must timely adopt the various initiatives to retain and improve its market position.

- Customer focus and commitment, innovation and change, competitive excellence and commitment to quality are the foremost business initiatives.

- Win-win situations with the suppliers, use of advanced manufacturing technology and flexibility in the manufacturing systems are the important aspect to be looked upon in a competitive market environment.
- Cross-functional teams within the company and with vendors wherever required has helped in achieving business competitiveness.
- The case of MSIL has amply demonstrated that when it came to take the initiatives, it had always at front taken the various business measures in-house or at vendors end to kept its position as market leaders in passenger car market.

Advanced manufacturing technology: AMT's have always played a vital role in the company success. The systematic, timely and planned use of AMT helps the company to achieve its business objectives.

- The important factors for the implementation of AMT's includes the fostering of manufacturing flexibility, enhancing the design capabilities, improving the productivity and attain quality leadership in the market place.
- Adoption, adaptation and further development of technology through local R&D efforts help the organizations to reduce the cost of their product.
- Organizations must emphasis on VA/VE to cut down costs.
- Use of IT enabled systems helped the organizations to reduce the inventory level, promote E Sourcing, enhance various dimensions of manufacturing flexibility, control waste and improve employee connect. Organizations that adopted ERP are able to achieve manufacturing competitiveness and perform better in the global market.
- MSIL is working towards localization, development and testing of products - both new and existing. This would help in indigenization of various vehicle aggregates at lower costs. The number of engineers in Maruti Suzuki R&D went up from 269 to 430 during the year 2007. In house R&D has helped the company to indigenously develop robots that in course helps significantly to achieve the volume flexibility. The company has increased plant capacity by robots and automation so as to reduce cycle time. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization has further improve and upgrade existing models for comfort, style and value for money. Alternative fuels like CNG, LPG, which could help make environmentally friendly vehicles are being worked upon.

Sourcing Practices: Company suppliers have been the partners in growth and turnaround. Adoption of different sourcing practices ranging from 'make or buy' decision to the 'early involvement of supplier at design stage', have emerged as a win-win situation for both buyer and supplier.

- Speed of capacity changeover in manufacturing system and adaptability to customer needs and requirement has emerged as most important factors for adopting the sourcing practices.
- Suppliers' technological competences, improvement in product variety and low delivery time have been the important factors to adopt different sourcing practices.
- Organization relies on small but high quality suppliers and strives to establish long-term relationship with suppliers.
- Suppliers are trained and helped to achieve various business parameters more efficiently and effectively.
- Early involvement of suppliers triggers innovations at the designing stage itself. This has further lead to achieve cost target approach at design stage itself.
- Shift has been witnessed from capacity to system supplier for an organization.
- Organization has witnessed the marginal decrease in product cost and substantial increase in net profit as a result of adopting and developing sourcing practices.
- Supplier flexibility, consistency, technological capability, level of cooperation and financial condition plays a significant role in supplier selection criteria.
- Cross-functional and cross-company efforts to increase flexibility and eliminate uncertainties have created the level of performance needed to create competitive advantage.
- In order to improve quality and generate economies of scale, MSIL has reduced the number of suppliers of components in India. MSIL has delivery instruction systems that helped in reducing both inventory levels and lead times required for the supply of various components and sub-assemblies, and enable the suppliers to more efficiently plan and dispatch their products. Component development capabilities of the suppliers have been upgraded through MACE and are helping us develop new models with shorter lead-time and enabling company to innovate successfully in new tools and fixtures with local expertise. Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage.

Manufacturing flexibility:

- The organization relies on adoption, adaptation and further development of manufacturing technology and infrastructure in house to achieve volume, modification and delivery flexibility. Also, the involvement of vendors in providing capacity support helped organization in achieving volume flexibility.
- Early involvement of suppliers for component design and development and supplier competencies has impacted the achievement of delivery flexibility. The significant use of technological and sourcing aspects helps the company to achieve the delivery flexibility leading to the introduction of new products with minimal lead-time.
- The augmentation of facility with new technology and the specialized technological capabilities of supplier(s) have helped the organization to achieve the modification flexibility.

5.2.12 Action Suggested

The business initiatives taken by MSIL depict their success story against competition. The stagnation of market share is inevitable, but still MSIL has been a market leader and selling more cars than any other manufacturer in Indian context. The indigenization of technology, promotion of R&D efforts in-house, implementation of information and communication technology in a phased manner, strong support of component and strategic collaborations with supplier base has helped the company to achieve different dimensions of manufacturing flexibility, quality leadership, cost cutting and achieving short delivery time of new or modified products. Like the Plan, Do, Check and Act (PDCA) cycle, the company should plan new initiatives further and implement them, check their results and act again. All the initiatives taken by MSIL have been quite effective, and must be continued. The company has to further enhance its technological competence and continually employ VA/VE techniques in house and at vendors place to improve the various business performances.

5.2.13 Performance Expected

Major factors of importance for achieving manufacturing flexibility at tactical and strategic level that need to be closely monitored in this case with equal importance are adoption, adaptation and further development of manufacturing and infrastructure technology and use of various sourcing practices, including early involvement of supplier for developing new or modified component.

5.3 Sona Koyo Steering Systems Limited (SKSSL)

Sona Koyo Steering Systems Limited (SKSSL) is a technical and financial joint venture company of Koyo Seiko Company, Japan the global technology leader in Steering Systems. Named as a Global Growth Company in 1997 by the World Economic Forum, the company is now well positioned to lead the Indian Automotive Component Industry to Global Standards in the coming millennium. SKSSL is the first steering systems company in the world to have bagged the prestigious Deming award, the world's most coveted honor for excellence in Total Quality Management. The company has achieved ISO 10015 certification from Geneva based AdeQuaTE (Academy of Quality in Training and Education), the only agency in the world approved by ISO for providing this certification.

Sona Koyo's product portfolio includes two types of products -steering systems and driveline products. The steering systems portfolio includes Manual Steering, Hydraulic Power Steering, Steering Column and more recently introduced Column-type Electronic Power Steering Systems. Driveline products include case differentials, rear axle assemblies and propeller shafts. In order to enhance the competitive edge, company regularly worked on improving efficiencies across the entire production process. This includes focused activities like value analysis and value engineering (VA/VE), vendor rationalization, promoting increased localization and improved balancing of production lines. Across most of its facilities, Sona Koyo continues to adopt lean manufacturing techniques and Toyota Production Systems. The company also believes in fully utilizing its existing assets.

5.3.1 Business Initiatives and Strategy

Sona Koyo is the largest supplier of steering systems topassenger vehicle manufacturers in the country. SKSSL is a tier-I vendor of steering systems and many other components to various automobile manufacturers (OEM) like Maruti Suzuki India Limited, Hyundai Motors, Mahindra and Mahindra, Either tractors and Telco. While the company intends to maintain its dominant position in thedomestic market, it has identified exports as a thrust area and has targeted 35 per cent of its revenues to come from exports by 2010. Sona Koyo also recognizes export as an important element of its strategy for long-term growth. The company has planned to invest in localization projects of both Hydraulic and Electronic Steering Systems to ensure sustained cost competitiveness.

The vision of the company is to become a world-class quality supplier of auto components. For achieving this, company identifies world leaders in technology and form strategic alliances with them. Sona benefits from these leaders in technology as well as management and production techniques. A technical centre is being developed in Gurgaon for development purposes. The suppliers are also instructed and aided in upgrading their quality and in adopting modern production techniques, by the company Supplier Quality Assurance (SQA) department. By helping its suppliers upgrade their quality and production and management techniques, Sona improves the quality of its own products.

In view of the growth opportunities presented by both domestic and international markets, Sona Koyo has taken a conscious decision to invest in both scale and technology. The objective is to develop capabilities to become a provider of end-to-end solutions, and thus transit from being a vendor to a full-fledged steering solutions provider. This requires developing an efficient and robust supply chain to service the enhanced capacities, maintaining high quality standards, and building product designing and testing capabilities through investment in research and development.

The company recognizes that building sufficient capacity is the key to attaining the next level of growth. The focus is also to become a "full service supplier" in addition to manufacturing, where company provides a complete suite of services ranging from product designing to manufacturing to testing and validation. This should enable increased penetration to global OEM accounts. In order to build on these capabilities company has been focusing on creating global manufacturing capacities, improving internal efficiencies and investing in technology infrastructure to create a complete back-office engineering support base.

The company strategy is to continuously improve Sona's operational efficiencies, through continuous improvement i.e. 'Kaizen', which creates a culture of small improvements through experimentation in every process in the organization. The company ensures continuous improvements and up gradation of processes within the organization. There are still a few areas where company needs substantive improvements and these are mainly in the Supply Chain and Logistics areas for which detailed road maps have been made for up gradation and are under implementation.

The snapshot of the achieved milestone and the business strategy decisions are delineated and presented in the Table 5.8.

Table 5.8 Milestones of Sona Koyo Systems Steering Limited (SKSSL)

Jan-85	Technical Agreement with Koyo for Manual Steering Gear and Column.
Feb-86	Sona Steering enters a Joint Venture agreement with Maruti Udyog Ltd.
Oct-87	Sona Steering Systmes Ltd. Commences production.
May-88	Sona Steering Systems Ltd., a JV with Maruti, lists through an IPO.
Jul-92	Koyo acquires 8% stake in Sona Steering Ltd.
Aug-94	Sona Steering Certified as an approved vendor to Koyo.
Sep-94	Incorporation of Mahindra Sona Ltd.
Mar-95	Mahindra Sona acquired the MSL Division of M&M.
Jul-95	Technical collaboration with Koyo for Power Steering Gear.
Dec-95	Joint Venture company formed with Mitsubishi Materials -Sona Okegawa Sona Somic Lemforder Components commences production.
May-97	Koyo increases stake to 20.5%.
Nov-97	Sona Cold Forgings commences productions.
Oct-98	Sona Steering name changed to Sona Koyo Steering Systems Ltd.
Nov-98	Sona Okegawa commences production of bevel gears for domestic market and exports.
Jan-99	Major exports to USA begin for Mahindra Sona Ltd.
Nov-04	Acquire 21% stake in Fuji Autotech France S.A.S.
Nov-03	Sona Koyo receives Deming Quality Award.
Sept-04	Sona Koyo inaugurates 100% EOU in Chennai.
Nov-05	Received Frost & Sullivan Manufacturing Excellence Award
Apr-07	Established plant at Dharuhera near Gurgaon
May-07	Received Teri Corporate Environmental Excellence Award

The company has invested in advanced manufacturing technology in the recent years to expand its capacities and scaling up for the greater global opportunities. The company not only intends to supply overseas markets, but also retain the number one position in India. In exports, the company plans to sell competitively priced and high quality Manual Steering Sub-Assemblies to their partner JTEKT, USA. The company has also commenced exports to Fuji Autotech Europe (FAE).

The company is committed to its investment plans for setting new plants near other OEMs in the next few years. The company would also be investing in localization projects of both Hydraulic and Electronic Steering Systems to ensure sustained cost competitiveness. All these measures are based on strong foundation of TQM and TPM principles and its commitment to R&D. The company expenditure on R&D increased from 0.8 per cent of net sales in 2006-07 to 1.5 percent in 2007-08. However, with their increased dependence on virtual prototyping and testing, the cost of making physical prototypes has reduced considerably. Sona Koyo will have to continuously innovate and adjust to the needs of the market.

5.3.2 Performance Indicators

The snapshot of various financial performance indicators of the company and their trends has been presented in figure 5.3.

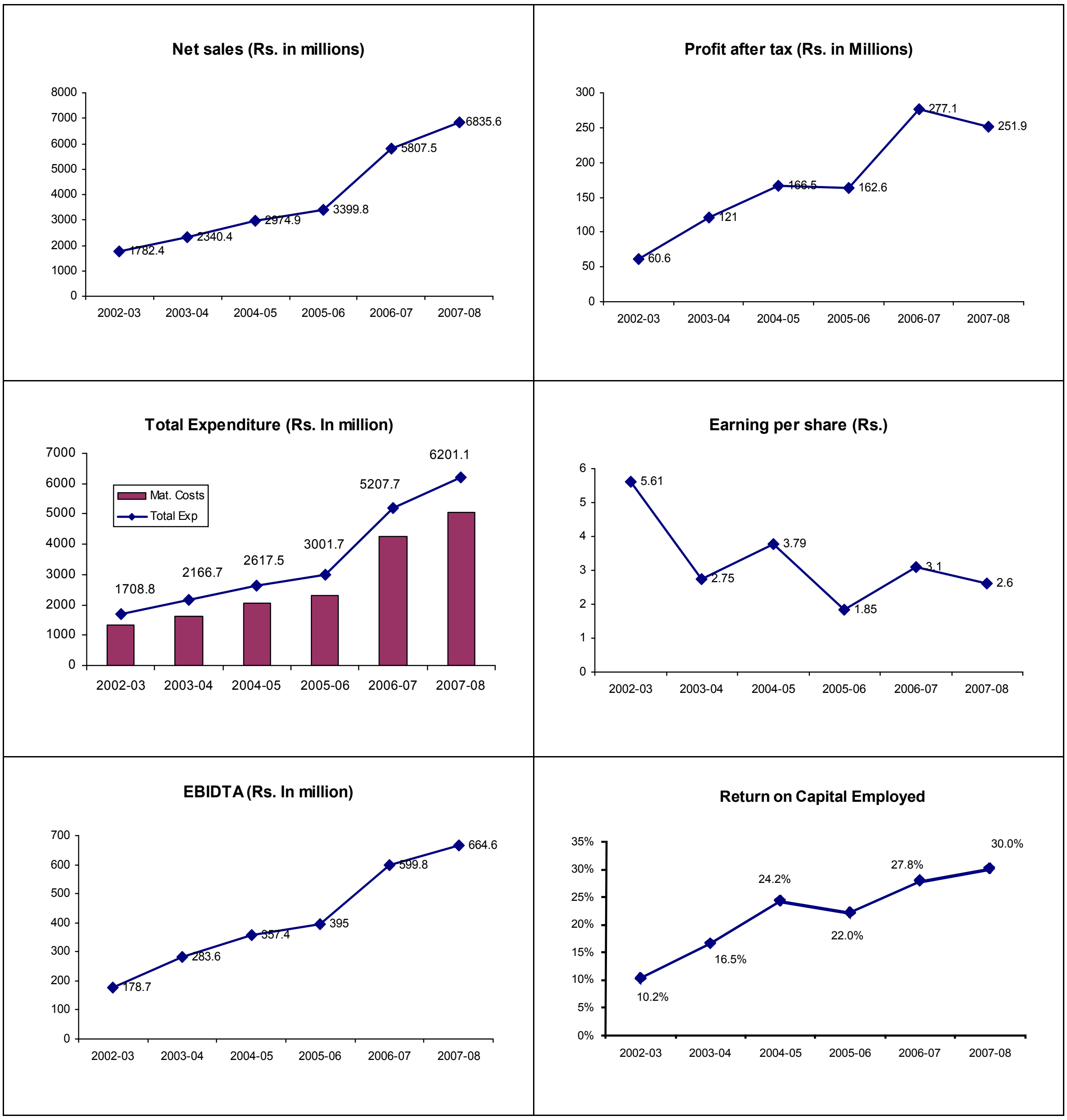


Figure 5.3 Performance indicators of SKSSL

Net sales increased by 27.1 per cent from Rs. 2,340 million in 2003-04 to Rs. 2,975 million in 2004-05. It was increased by 14.2% from Rs. 2,975 million in 2004-05 to Rs 3,400 million in 2005-06. The sales growth was primarily on account of exports, which got doubled as compared to the previous fiscal. Net sales increased by 70.8% from Rs. 3,400 million in 2005-06 to Rs. 5,808 million in 2006-07 and further increased by 17.7% to Rs. 6835.6 million in 2007-08.

Profit after tax (PAT) increased by 37.7 per cent from Rs.121 million in 2003-04 to Rs.167 million in 2004-05. However, net profit declined marginally from Rs 166.7 million to Rs 162.6 million. During 2005-06, due to the steep hike in petroleum product prices, extraordinary cost of air freight for overseas supplies to meet delivery deadlines and high tooling costs for development of new products during the year. The company witnessed only a marginal drop in its operating margins, primarily on account of its relentless cost reduction focus. One of the focus areas has been on improving operational efficiencies by de-bottlenecking existing production lines. PAT increased by 70.4 per cent - from Rs.163 million in 2005-06 to Rs. 277 million in 2006-07. During 2007-08 the profit after tax has registered a negative growth of - 9.1% because of higher depreciation and interest costs due to capacity expansions.

Total Expenditure is showing a continuous growth rate over the last years. It increased by around 14% from Rs. 2617.5 million in 2004-05 to Rs. 3001.7 million in year 2005-06, increased drastically by around 73% to Rs. 5207.7 million in year 2006-07 and further increased by around 19% to Rs. 6201.1 million in 2007-08.

Earnings per share (EPS) increased from Rs.2.75 in 2003-04 to Rs.3.79 in 2004-05. Following the trend of net profit, it marginally decreased by 2.4% to Rs. 3.70 for year 2005-06. The company decided to give a bonus share @ 1:1 to its existing shareholders. So the net EPS worked out to be Rs. 1.85 for the year 2005-06. Further, it increased to Rs.3.1 in 2006-07. Then in 2007-08, it showed a fall of 9.1% to Rs. 2.60/- because of higher interest costs and depreciation due to capacity expansions

EBIDTA is showing a continuous growing trend over the last years. It increased by around 11% from Rs. 357.4 million in 2004-05 to Rs. 395 million in year 2005-06, increased by around 52% to Rs. 599.8 million in year 2006-07 and further increased by around 11% to Rs. 664.6 million in 2007-08.

Return on Capital Employed (ROCE) is the ratio of EBIDTA to total capital employed. ROCE during 2003-04 was 16.5% which increased to 24.2% in 2004-05. During 2005-06, it reduced to 22% due to high investment in capacity expansion. Further, it rose to 27.8% in 2006-07 and 30% in 2007-08.

5.3.3 Manufacturing Capacities and Capabilities

The company is in the process of transforming itself to a "full service supplier" where company provides a range of services ranging from product design to manufacturing to testing and validation. The company has also worked with a large OEM on their new vehicle program and has created capacity for new generation commercial vehicle steering column technology from the technical collaborator in Europe in the recent past.

Most product lines, especially in steering parts operated at full capacity with increased levels of outsourcing, in the recent years. Consequently, company embarked on a capacity expansion plan and spent Rs.370 million for capacity expansion and added Rs.360 million worth of fixed assets. Sona Koyo has created global capacities in steering and driveline components.

The company has aligned and strengthens its geographic presence in the country by setting-up facilities that take into account new projects and capacityexpansion plans of the various vehicle manufacturers. By doing so, the company has been able to be at close proximity to its customers and unlock greater value from its operations. In line with this, Sona Koyo has finalized its plans for Greenfield investments in Uttaranchal and West Bengal. In addition to the ongoing expansion of manual steering systems, the company also has plans to substantially increase the hydraulic power steering capacity at the Chennai plant.

Sona Koyo has also recently entered into a majority ownedJoint Venture "Arjan Stampings Private Limited" with Arjan Auto Private Limited. The joint venture will manufacture stamped parts used by customers in Europe for Steering Columns and Seat Recliners. This will enable the company to capture a share of sheet metal stamping exports to Europe as well as exercise greater control over the tier-II / III auto component business. In addition, the company is exploring other tier-II components for manufacture, since the export potential of these components will be significant.

Quality: In the current market scenario, customer expectations on product performance are becoming bigger. Therefore, there is a constant need to innovate and deliver high quality products. Sona Koyo has always stressed on its quality managementinitiatives to continuously improve its efficiencies and meet customers' expectations.

The company started a major initiative called 'High Volume Production Trial' (HVPT). The purpose of HVPT - which is conducted before start of production for a new item - is to judge whether or not the mass production can be started. This enables smoother launch of a new product or a new production line. The result of this exercise can be seen in terms of the reduction in rejection of new products. Both in-house rejection and customer rejection of new products have come down.

The company also introduced 'Quality Gate 20', which is a sequence of processes and approval activities for the development of new products. Every gate indicates achievement of a milestone in the product development cycle; and satisfactory closure of the activity is essential before moving on to the next activity.

Cost: The company undertook a cost management programme which included improvements in operational efficiencies through activities like value analysis and value engineering (VA/VE), vendor rationalization, increasing localization and streamlining the existing production processes. Localization of hydraulic steering is underway and will be followed by increasing localization of the electronic power steering. There are three key elements of costs - raw material, manufacturing, and employee costs. The raw material cost continues to follow a decreasing trend and reduced as a percentage of sales primarily on account of lower average steel price, internal VA/VE programs and renegotiation with the suppliers.

5.3.4 Role of Technology

Having realized the necessity of using technology as a competitive tool, the company has been actively developing its in-house R&D capabilities. From being a pure manufacturing organization, the company currently has been actively partnering customers (OEMs) in product development. The company has acquired capabilities to design, develop and test most of its manual steering gears and columns. In 2004-05, there are over 48 Sona Koyo designed products. New products, introduced in past three years, accounted for over 44% of total sales.

Sona Koyo significantly developed its testing facilities in the recent years. Besides strengthening bench-testing facilities, the company has built-up capabilities for performance testing of the steering system on a vehicle. The company has also made substantial investments in instrumentation and software. This improved company market positioning, and go a long way in potential customers choosing the company for their new development programmes.

In line with its objective to become a preferred supplier to global customers, the company continues to pursue its strategic objective of harnessing its in-house design and development capabilities. The company also signed a technical collaboration agreement with two Russian firms, Power Electronics of Siberia and Sibtehnomash to conduct joint research on steering applications and electronics with a focus on control systems.

The company has acquired technology for electronic powersteering systems for passenger cars from its partner JTEKT as well as steering column for commercial vehicles from Fuji Autotech AB, Sweden. As a next step, the company is working on increasing localization of these technologies to become more competitive, and enhance its market position.

In addition, the company has also tied-up with premier research institutions such as IIT Delhi and IIT Mumbai to develop future technologies in Steering Systems and components thereof. The company has made investments in R&D and has two exciting projects in the pipeline. One is company's version of the electronic power steering, for off-highway applications called EPAM (Electric Power Assist Module) and the other is a joint development with IIT Mumbai called Steer-by-wire. The company significantly upgraded its testing facilities. Currently, the company is self-sufficient in testing hydraulic products, and is now exploring the idea of developing this facility as a testing hub for its global partners.

Opportunities created due to globalization in form of gigantic markets lead SKSSL to manufacture world class products using most advanced technologies. Similarly, the threats caused by globalization inform of immense competitors in domestic market force SKSSL to keep its technology and product quality abreast with competition. SKSSL has well laid new technology adoption polices. These policies are updated and reviewed periodically and also track technology adoption costs. Among the critical barriers to technology adoption in SKSSL are (i) cost of training & education adoption (ii) cost of new technology, and (iii) skill deficiency for new technology. The company has clear processes for carrying out technology projects and a good system for assessing these. It carries out post project reviews as well. SKSSL has very cordial relationships with the suppliers of new technology, thus facilitating its successful adoption. Further these suppliers of new technology are selected using thorough & extensive evaluation process and this selection affects its process of new technology adoption.

The company efforts towards technology adoption, innovation and R & D along with the benefits derived during the recent past has been presented in the Table 5.9.

Table 5.9 Role of technology, innovation and R&D at SKSSL

EFFORTS MADE TOWARDS TECHNOLOGY ADOPTION, INNOVATION AND R & D	BENEFITS DERIVED TO TECHNOLOGY ADOPTION, INNOVATION AND R&D
Towards technology adoption and innovation • The company has acquired the manufacturing technology for Column Type Electric Power Steering (C-EPS) from its Collaborator, JTEKT Corporation, Japan and currently in the second phase of localization. • The company is in the final stages of setting up core manufacturing facilities to manufacture valve assemblies for Hydraulic Power Steering locally using the technology from its collaborator. • The company is developing technology for advanced featured Steering Columns for commercial vehicles. • Developed capabilities and virtual simulation & testing of new products before they are released for manufacturing. • Localization of critical parts of Power Steering continued.	**Benefits due to technology adoption, adaptation and innovation** • Localization of electric power steering would enable company to be more cost competitive in domestic market as well as it would open opportunities for the company to supply parts back to its collaborator. • By acquiring high-end manufacturing technology for steering columns, company aims to be able to cater to customers' requirement of next generation vehicles. • Localization of valve assembly for hydraulic power steering gear would enable import substitute as well as reduce the time to market for new projects. • The company has become more competitive in prices due to localization of parts in the global markets.
Specific Areas in which the company has carried out R&D • The company is in the process of developing an alternate cost effective Electric Power Steering technology for off-high way application completely on its own. The engineering prototype has been developed and currently under final evaluation stage by a reputed overseas OEM. • The company is closely working with some premier research and academic institutions within and outside the country to develop futuristic product technologies. As one of the important project, conceptual prototype of Steer-by-wire control application has been developed with Indian Institute of Technology, Mumbai.	**Benefits derived as a result of R & D** • The R&D initiatives would enable the company to develop its own technology, designs and patents that can be used in steering products as well as in other potential applications. Since electronics will be increasingly used in the automotives in future, some key R&D initiatives are mainly focused on developing necessary automotive electronics knowledge. • With the association of research institutes, the Company aims to co-develop advanced futuristic product technologies to retain its position in the market. • The company has been able to significantly reduce the customer rejections and warranty due to design at new product development stage itself.

Adoption of Information Technology: Over the years, IT has evolved as a key function in supporting Sona Koyo to meet its organizational goals. It plays an important role in supporting the company's focus on capturing operational efficiencies, manufacturing flexibility, developing new products at low cost and interfacing with customers and suppliers.

The company reviewed its entire IT infrastructure, and focused on consolidating, integrating and optimizing existing systems. This involved stabilizing continuous business process flows of existing software and integrating the enterprise application interface. There were two such major initiatives – integration of the design software "Wind chill" with the ERP system and linking enhanced design software (called PDM-Link) with the new product development software (called Project-Link) to create an integrated system for new product development.

The ERP implementation has enabled the company to expedite responses to customers' orders and queries, reduce inventory, shorten production cycle time, improve quality, enhance the efficiency of delivery of products and services, and strengthen in-company coordination. ERP applications allow the redefinition of the competitiveness and enhancement in business process performance through the adoption of the best business practices that are embedded in the ERP applications. The applications of ERP includes, transfer of inventory ownership to the concerned departments, which is helping in proper tracking of the inventory and usage of procured Advanced Schedule Planning module from Oracle to automate schedules. Using ERP, the company is linking up with their suppliers and customers located in any part of the world and employees are sharing information with each other on a real-time basis. The Line Stoppages due to material shortage reduced drastically after implementation of ERP system. The company has also invested in SCADA system machines, which allow two-way information, flow across the shop floor.

A dedicated Consolidated Data Center was developed for Sona Group at the Gurgaon plant for running applications that handle the core businesses and operational data of the organization. This centralization of the IT system has reduced the need for on-site support personnel, and has enabled much better utilizations ofIT resources across the company.

Currently, all company locations are connected directly by high-speed optical fibre Radio Frequency (RF) links. The company has implemented office automation applications, high-end security systems, virtual private network for administration and user mobility, and 'smart' technology to prevent misuse of services.

5.3.5 Role of Sourcing Practices

With most automobile manufacturers employing internationally benchmarked inventory management practices and delivery schedules, success in the auto-component industry depends critically upon an efficient and well-managed sourcing practices and supply chain. Supply chain management (SCM) has become a critical activity for Sona Koyo, due to focus on new customer locations, exports and new suppliers for new products or projects. The company has devised plans to be more integrated with its customers and suppliers to achieve its objective of creating and maintaining a seamless supply chain. The company plans to work in close partnership with its channel partners to eliminate inefficiencies and endure world-class process in delivery of auto-components to its domestic and overseas customers.

The company has reorganized itself internally to ensure low cost to its customers. The company has adopted a dual supplier policy for all bought-out items and is in the process of validating and rating new and existing suppliers. The company has also carefully reassessed component prices to reflect "true cost" thereby shedding off additional costs. These initiatives helped protect the company's operating profit margins in the current fiscal and will result in margin improvement in the next few years.

The company plans to harness its IT infrastructure to connect its customers and suppliers - Project Link - that offers services like updated information on new product development to customers, releases schedules and information about invoice payment to suppliers. Through weekly inventory monitoring and creation of third party warehouses, the company's inventory turnover improved by over 36 per cent from 14 turns in 2005-06 to 19 turns in 2006-07. The company also expects to aggressively increase the coverage of third-party warehouses.

The company also took forward its VA initiatives. With a goal to supply defect-free parts at globally competitive rates, the company created a model aiming at lowering cost while sustaining partnership with our existing suppliers. The company has started evaluating the past performance of suppliers and set cost reduction targets for the future. It also introduced fact-based negotiations, cost control and elimination of wastages at suppliers' end, while building alternate sources. The procurement function was also centralized across all plant locations, and six commodity-sourcing groups were formed. This is expected to result in a further reduction in cost due to economies and better resource management.

The company is also looking at utilizing e-procurement solutions to control costs. A cluster of 23 suppliers was formed to train and inculcate best practices in quality management. The company also identified a group of suppliers to implement a common cost-effective ERP solution for them. This has enable seamless sharing of information between the supplier and Sona Koyo, and is expected to result in improved efficiencies. The company expects to extend this facility to all suppliers.

The company has planned to achieve its vision of becoming a supplier of choice to global customers through excellence in quality at par with global auto suppliers. The company has been continuing to implement Total Quality Management (TQM) and Total Productive Maintenance (TPM) practices across functions and processes. The practices are being recognized and appreciated by the customers and competitors while the company is forming clusters of suppliers to ensure they start adopting these practices

The company also considers all its suppliers as partners. To strengthen this partnership and develop the capabilities across its supply chain, the company has been advocating TPM and TQM practices with suppliers. Due to these initiatives some of the awards received during the 2006-07 includes “Cost Reduction” and “Best Effort and Quick Response” Award from Toyota Kirloskar Motors Limited and for “tier-2 vendor up gradation and implementation of Kaizen and Maruti Production System” from Maruti Udyog Limited.

5.3.6 Social and Environmental Aspects

Sona Koyo is conscious of its social responsibilities, and believes in making a difference for the better in the area of its influence. Environment, community development and education are areas that are of keen interests to the company. The company has constituted a special committee called 'CSR Council' comprising members across all levels to secure a just and equitable process of eco-social development.

The company's continuous stress on improving the knowledge of its workforce is also reflected in the increase in hours of training per worker, which has increased from 9.5 hours in 1998 to 75 hours in 2005-06. The company is laying greater emphasis on team building as well as creating an organization, which is flexible and focused on operational efficiencies, quality and cost. The end objective, of course, is total customer satisfaction. The improved work culture is reflected in the decrease in worker absenteeism, which has come down from 11.29 % in 1998 to 8.1% in 2005-06. To enhance employee satisfaction, it has taken steps to align remuneration with the market, devise schemes to link pay to performance, develop competency models and training programmes for quick transfer of competencies to new employees.

The company carried out various energy saving initiatives and upgraded the effluent treatment plant. Sona Koyo has an ambitious target to become a 'Zero Waste' company by 2010. The company also proposes to take initiatives in upliftment of the rural population in India through dissemination of education, employment and other initiatives.

5.3.7 SWOT (Strength, Weaknesses, Opportunity, Threat) Analysis

On the basis of the study carried out in SKSSL, SWOT analysis has been done in which the strengths, weaknesses, opportunities and threats for this company has been identified. Table 5.10 shows the SWOT analysis at SKSSL.

Table 5.10 SWOT analysis at SKSSL

Strengths	Weaknesses
• International reputation of Sona Group. • Joint venture of Maruti Suzuki India Limited. • Technological and financial support from Koyo Seiko Company Ltd, Japan. • Tier-I vendor to many OEMs supplying steering systems. • Adherence to Japanese work system and group work culture, implementation of Toyota Production System (TPS), accreditation to ISO 9002 and QS 9000, use of TQM and TPM methodologies. • Committed manpower and team spirit. • High level of commitment from top management. • High level of flexibility in changing products and processes.	• Main dependence on Maruti Suzuki India Limited. • Adapting to The Indian government rules and regulations. • Costly imported components in the power steering systems.
Opportunities	**Threats**
• Establishment of more automobile companies in India. • Strategy of OEMs to procure parts and components from tier-I vendors only. • Growing demand of power steering systems. • Growing exports avenues in the neighboring countries.	• Squeezing profit margin. • A big unorganized sector producing non-genuine spares parts for cars and utility vehicles. • In-house manufacturing of steering systems by new MNCs or imports. • Escalating prices of raw materials.

5.3.8 Status of Manufacturing Flexibility

Sona Koyo has increased its capacity and capabilities by introducing a number of modified or new products and by reengineering its manufacturing facilities in terms of de bottlenecking the existing production lines. The company has transformed its position to technology supplier by patenting its technology and products, reduced inefficiencies in the entire supply chain. The company has invested in technology and scale to efficiently deliver the entire product range as per OEM requirements. Significant investment in design and infrastructural technology has helped the company to attain flexibility dimensions in terms of volume, modification and delivery. The company has significantly invested in technology infrastructure to achieve volume flexibility in addition to its presence excellence in manufacturing technology. The focus of the company to become a global leader in total solution provider of steering systems has created a need to provide manufacturing flexibility, quality, and reduced cost.

The company has adopted the technology from its alliance partners to reduce the lead-time to new product introduction. It has penetrating its facilities to become a system supplier to its OEM apart from manufacturing aspects only. Increased investment in R&D and localization efforts for the imported technology has helped the company to deliver the delivery flexibility in terms of deliverance of new products to its OEM with shorter lead time and competitive cost.

The supplier role has been restricted mainly to the operational and tactical level flexibility dimensions. The company has build up cross-functional teams with its OEM for introducing the product modifications. The company held its responsibility for the operational and delivery aspects of its products to its OEM. VA/VE teams with its OEM and tier-2 suppliers helped the company to eliminate waste, improve flexibility, and enhance productivity and quality. The collaborated effort of the company and its OEM to train and develop the operational and design capabilities of tier-2 suppliers has helped the company to modify its products.

Integrated IT applications such as Enterprise Resource Planning (ERP) systems, Supply Chain Management (SCM) systems has helped the company to gain considerable competitive advantage through increased flexibility; improved quality and shorter production lead times. These applications have helped the company to produce customized products with short lead times at production costs that reflect the efficiencies typical of mass production operations.

Volume flexibility: Volume flexibility allows organizations to respond to both decreases and increases in the aggregate demand at a given configuration. The company recognizes that building sufficient capacity is the key to attaining the next level of growth. The company has created additional capacity to meet growing demand in the recent years. The company planned to spend another Rs.500 million on increasing existing product capacities, and a further Rs.300 million to set up capacities to produceColumn-type Electronic Power Steering systems(C-EPS), a new product line. These investments, coupled with the continuous efforts at de-bottlenecking existing production lines, provide with theincreased capacity required to better service the expanding market demand. Capacity for manual steering gears is being increased from 1million units to 3 million units. Hydraulic power steering capacity has been increased to 500,000 units. Sona Koyo added capacity for manufacturing 300,000 units of C-EPS at its Gurgaon plant that already operated at high levels of capacity utilization.

Also, the company has been focusing on creating global manufacturing capacities, improving internal efficiencies and investing in technology infrastructure to create a complete back-office engineering support base. The company has invested in infrastructural technology by having process integrated ERP solutions, representing computerization in core business processes, process automation & integration to achieve volume flexibility. Furthermore, the short-term volume flexibility has been considered vital to the mobility, uniformity, and stability of manufacturing systems. The company believes that an accurate production program forecast increases the volume flexibility since changes in demand can be anticipated.

The company has also increased the level of outsourcing manufacturing to achieve the volume and capacity to fulfill their OEM increased demands.

Modification flexibility: The company has currently a range of hydraulic power steering systems, electric power steering systems, manual rack & pinion steering systems and collapsible, tilt and rigid steering columns for passenger vans and MUVs and has a past record of continually modifying the products and in result growing delivery and market share. The company has a capacity of producing minor alterations in product design to meet customization. The company has also been able to improve existing models and offer many variants in each category.

Sona Koyo has invested in R&D for increasing the localization of technology adopted in the past to meet customization needs and modifying the products as per the local market conditions. The company has adopted various quality management techniques to improve its ability to modify product in terms of enhanced flexibility, quality, reduced customer rejections and high first pass yield. Also, the collaborated effort of the company and its OEM to train and develop the operational and design capabilities of tier-2 suppliers has helped the company to modify its product range in terms of cost, quality and operating efficiencies.

Delivery flexibility: The vision of the company to become the tier-1 supplier of choice globally has evolved its need to continually invest in the technology and supply line. The demand of the markets and OEM to introduce new products quickly has necessitated the increased role of adopting, adapting and further localization of the technology and R&D efforts for the company.

From being a pure manufacturing organization, the company currently has been actively partnering customers (OEMs) in product development. The company has acquired capabilities to design, develop and test most of its manual steering gears and columns. The company has developed capabilities and virtual simulation & testing of new products before they are released for manufacturing. The company started a major initiative called 'High Volume Production Trial' (HVPT) in the recent past. The purpose of HVPT - which is conducted before start of production for a new item - is to judge whether or not the mass production can be started. This enables smoother launch of a new product or a new production line.

Sona Koyo is closely working with some premier research and academic institutions within and outside the country to develop futuristic product technologies. One of the project related to conceptual prototype of Steer-by-wire control application has been developed with Indian Institute of Technology, Mumbai. The company has been able to significantly reduce the customer rejections and warranty due to design at new product development stage itself. On the whole, the role of the different supplier practices has been limited to the attainment of tactical level flexibilities and minor process or design modifications. However, the enrichment of technological aspects of the tier-2 supplier by the company and parent OEM has resulted in with supplier involvement in design and development stage.

Overall, the status of tactical and strategic level manufacturing flexibilities in the context of the study for MSIL has been graphically revealed in figure 5.4.

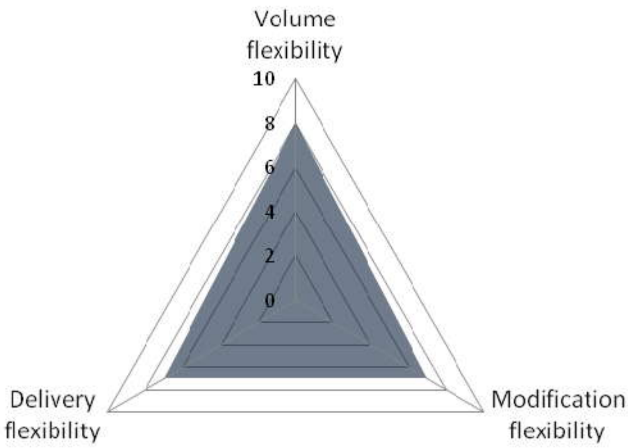


Figure 5.4 Status of manufacturing flexibility of SKSSL

5.3.9 Relative Performance of Technology and Sourcing Practices

Investment in manufacturing, design and infrastructural technology and localized R&D efforts has helped the company to retain and further increase its market share in the highly competitive and turbulent market environment as leading tier-1 supplier. At the same time the involvement of the vendors at operational and tactical level helps in pacing the rate of growth for the company. The relative impact of adopting new technology vis-à-vis sourcing practices for achievement of different business objectives has been presented in the Table 5.11.

Table 5.11 Impact of adopting new technology and sourcing practices at SKSSL

		Impact of adopting new technology on performance objectives	**Impact of adopting sourcing practices on performance objectives**
1. PRODUCT QUALITY			
i.	Performance of products	++++	+++
ii.	Features of products	++++	+++
2. DELIVERY			
i.	Speed of delivery	+++++	++++
ii.	Number of customized product offered	+++++	+++
iii.	New product lead time	+++++	++++
3. FLEXIBILITY			
i.	Variety of modified products	++++	++++
ii.	Delivery of innovative products	+++++	+++
iii.	Capacity to change product volume	++++	+++++
3. COST			
i.	Product cost	+++	+++
ii.	Cost of future product innovations	+++	+++
5. EFFECT ON MARKET SHARE		++++	+++
6. NET PROFIT		++++	++++
7. OVERALL PERFORMANCE		**HIGHLY SATISFIED**	**MODERATELY SATISFIED**
(+) significantly decreased, (++) moderately decreased, (+++) remained the same, (++++), moderately increased, (+++++) significantly increased.			

The adoption of different sourcing practices has significantly increased the tactical level flexibility and profit aspects of the company; along with moderately decrease in the product cost. However, new technology has a significant positive impact on various delivery, flexibility and quality parameters. It further facilitates the company to retain its market share and adjust to market requirements. In order to meet market requirement, the

SKSSL have always been adopting new technologies to keep its products abreast with those of international competitors.

The level of dependency on different sourcing practices for achieving the various manufacturing flexibilities is presented in Table 5.12.

Table 5.12 Dependency on different practices for achieving flexibility at SKSSL

Sourcing Practice →	**OUTSOURCING OF MANUFACTURING**	**STRATEGIC SOURCING** ***(Outsourcing the in-house core competencies)***	**ADOPTION OF NEW TECHNOLOGY**
VOLUME FLEXIBILITY	++++	+++	**++++(Main focus infrastructural and design technology)**
MODIFICATION FLEXIBILITY	+++	++	++++
DELIVERY FLEXIBILITY	+++	++	**++++(Main focus R& D, technical collaboration)**
+ - Not dependent, ++ - Least dependent, +++ -Moderately dependent, ++++ - Highly dependent, +++++ – Fully dependent			

The role of manufacturing and infrastructural technology and supplier involvement in managing capacity fluctuations has come out be important factor for achieving volume flexibility. The company has invested in the localization of technology adapted for modifying the existing product range and delivering the new products. The collaborated effort of the company to train and develop the design capabilities of tier-2 suppliers has helped the company to modify its product range. Collaboration with the technology suppliers worldwide and pursuing the R&D efforts locally significantly influenced the achievement of delivery flexibility. The adoption of quality management techniques and cross-functional teams with the OEM has significantly helped the company to achieve delivery flexibility.

5.3.10 SAP Analysis

Based on the business strategy and initiatives taken by the SKSSL in the process of achieving the different manufacturing flexibilities, the situation-actor-process (SAP) analysis has been done.

Table 5.13 illustrates the SAP analysis at SKSSL while LAP synthesis is described in this section.

Table 5.13 SAP analysis at SKSSL

<table>
<tr><th>Situation</th><th>Process</th></tr>
<tr><td>

The company has obtained its technology for Koyo Seiko Company Ltd. of Japan through technical collaboration.
Market share and profit margin of MUL has affected the performance of this company because it is the main supplier of steering systems to it.
The company has diversified into allied products like UJ assembly and Rack and Pinion assembly.
SKSL has widened its customer base from MUL to other OEMs also, e.g. Hyundai, Eicher, Telco etc.
SKSSL as a tier-1 vendor to OEMs is dealing with tier-2 and tier-3 vendors, and has assured scheduled supply components to OEMs on JIT, and ERP solutions have improved the systems of the organization and changed the work-culture.

</td>
<td rowspan="3">
Technological Aspects

Technical collaboration with world leaders has helped in manufacturing of world-class products.
Optimal use of manufacturing facilities for flexibility and productivity increase.
Suitable change in technology for Electronic Steering systems.
Automation in the production area.
Increase in the partnership of Koyo Seiko Company Limited Japan for new technology alliance.
Increasing the customer's base and starting manufacturing of steering systems for utility vehicles and LCVs.

Sourcing Aspects

Creating and maintaining a seamless supply chain with the suppliers.
Identified a group of suppliers for implementing an ERP solution enabling seamless sharing of information and managing flexibility.
Participative management, suggestion schemes and cross-functional teams with tier-2 and tier-3 Suppliers.
Developing local vendors for timely supply of parts and components.
Implementation of TPM, 5S, and accreditations to Toyota Production System, ISO 9002 and QS 9000 in the company and selected vendors place.

</td></tr>
<tr><th>Actors</th></tr>
<tr><td>

Top officials of the company
Tier-2, Tier-3 vendors and other suppliers to SKSSL.
Original Equipment Manufacturer (OEM’s) for SKSSL.
Flexible and innovative engineers and supervisors to manage changing needs of the customers quickly.
Foreign collaborators to the company

</td></tr>
</table>

5.3.11 Learning Issues

Based on the detailed study and analysis of the business strategy and initiatives taken at SKSSL, the following leaning issues have emerged.

Technological Developments: The success of any company depends upon the level and effective management of its technological competencies.

- SKSSL has adopted the technology from its alliance partners to reduce the lead-time to new product introduction and further localize it to suit it to the market conditions within house R&D efforts.

- The company is penetrating its facilities to become a system supplier to its OEM apart from manufacturing aspects only.
- The company has largely invested in the infrastructural technology so as to integrate its various business operations within and with their suppliers and OEMs. This adoption has helped the company to enhance its capacity and capabilities in terms of attainment of tactical flexibilities, quality, and productivity and also reduce cost and waste.

Sourcing Practices**:** Case study of SKSSL has emerged with a major leaning issue, that success of vendors in tier -1category is dependent upon the success of its OEMs.

- The company has to continually adopt appropriate technology and optimally use sourcing practices so as to achieve business objectives including manufacturing flexibility, quality and cost competitiveness that in turn help the OEM to compete in the turbulent market environment.

Vendor Consolidation**:** It is learnt that vendor consolidation can result in enhanced quality and flexibility, reduce time to introduce new products and minor design modifications in the existing products.

- It is seen that SKSSL and its tier-2/tier-3 vendors have upgraded their facilities to meet the desired quality and quantity needs of their OEMs. Suppliers are instructed and aided in upgrading their quality and in adopting modern production techniques, by the company SQA department.
- Cross-functional teams within the company and with the vendors have helped in achieving business competitiveness.
- The company has identified a group of suppliers for implementing an ERP solution enabling seamless sharing of information and promoting e business, flexibility and competitiveness.

Manufacturing Flexibility: It is learnt that with large product mix, a company can make use of its facilities optimally. Starting with the mechanical steering systems and subsequently manufacturing of power steering systems, steering column and differential assemblies at the same plant, the company optimally upgrade and use its facility optimally to provide volume, variety and new product introduction.

- Significant investment in design and infrastructural technology has helped the company to attain flexibility dimensions in terms of volume, modification and delivery.
- The company is penetrating its facilities to become a system supplier to its OEM apart from manufacturing aspects only.
- The company has adopted the technology from its alliance partners to reduce the lead-time to new product introduction.
- The supplier role has reduced mainly to the operational and tactical level flexibility dimensions.

Strategic Change: Expansion of a manufacturing organization should be planned carefully. With a plan of manufacturing steering systems for other car manufacturer, the company preferred to select a new site near the OEMs. This strategy not only helped the company to reduce transportation cost rather helped the company in developing a new work-culture.

5.3.12 Action Suggested

The initiatives taken up at SKSSL depict the capability of organization to become the system supplier of total steering solutions to the OEM. The optimum use of facilities, introduction of new technology, deployment of various quality management techniques, increased effort in R&D facility has helped the company to achieve volume, modification and delivery flexibility and reduce cost, customer rejections and waste. The company has involved the supplier for capacity fulfillment needs grossly. The company must increase their focus on tier-1/tier-2 vendors and enhance their capabilities for design and modification at micro level. For further cost cutting, more systematic changes are required in the company.

5.3.13 Performance Expected

Major factors of importance for achieving manufacturing flexibility at tactical and strategic level that need to be closely monitored in this case are further development and indigenization of manufacturing and infrastructure technology through in house R&D and cross functional teams with OEMs and optimal use of various sourcing practices, including early involvement of supplier for developing new or modified component.

5.4 Moser Baer India Limited

Moser Baer India Limited (Moser Baer) is one of India's leading technology company, was founded in New Delhi in 1983 as a Time Recorder unit in technical collaboration with Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland. The company successfully developed cutting edge technologies to become the world's second largest manufacturer of optical storage media like CDs and DVDs. The company also emerged as the first to market the next-generation of storage formats like Blu-ray Discs and HD DVD. Recently, the company has transformed itself from a single business into a multi-technology organization, diversifying into exciting areas of Solar Energy, Home Entertainment and IT Peripherals & Consumer Electronics. The entire product range of the company includes Optical Storage Media (CDs, DVDs), Photovoltaic (Crystalline Silicon cells and modules), Entertainment (Distribution of movies, film production and theatrical distribution) and IT Peripherals and Consumer Electronics (Optical Disk Drives, Headphones, Keyboards, Optical Mouse, DVD Players).

Moser Baer has a presence in over 82 countries, serviced through six marketing offices in India, United States, Europe and Japan, and has strong tie-ups with all major global technology players. Moser Baer focused its business on the preferred OEM for all 12 of the world's optical media manufacturers and commands a 16% development, manufacture and supply of optical media across the globe. With a strong R&D thrust, the company has been able to lead the technology curve in the optical media business. In the process, it is among the very few Indian companies to have contributed to the establishment of new global technology standards. As a result of this single-minded drive and commitment, Moser Baer became the first storage media company in the world to ship HD DVDs. The company is today the only large Indian manufacturer of magnetic and optical media data storage products.

Moser Baer stands committed to supplying highest quality fully licensed media to its customers. The company manufactures photovoltaic cells and modules by straddling multiple technologies including crystalline silicon, concentrator, nano technologies and thin films. Moser Baer Entertainment offers home video titles in various Indian languages at unmatched prices and is also engaged in film production and theatrical distribution. The company has also initiated marketing of a series of IT Peripherals and Consumer Electronics gadgets.

Moser Baer's products are manufactured at its three state-of-the-art manufacturing facilities. It has over 6,000 full-time employees and multiple manufacturing facilities in the suburbs of New Delhi. The company's long-term strategy is to utilize its core mass manufacturing capabilities, especially in high technology and process-driven industry fields, to capitalize on the growing global trend towards outsourcing.

5.4.1 Business Strategy and Initiatives

Since inception, Moser Baer has always endeavored to create its space in the international market. Aiding the company in its efforts has been a carefully planned and sustainable business model - low costs, high margins, high profits, reinvestment and capacity growth. Along the way, deep relationships have been forged with leading OEMs, with the result that today there are hardly any global technology brands in the optical media segment that Moser Baer is not associated with.

The company possesses a high level of process know-how and builds on existing technologies. Also, it primarily aims to reduce processing cost and increase the flexibility of the processes and products. This enables the development of a competitive advantage in processing less complex products for multiple clients with as little set-up times and costs as possible. The company has a high development competence and an adequate level of process and product know-how and offers problem-solving competencies. The company more independently and often develops 'base' technologies at its own risk. Furthermore, the company even develops new products without a specific problem definition of its OEMs.

The snapshot of the achieved milestone and the business decisions are delineated and presented in the Table.

Table 5.14 Milestone and business initiatives of Moser Baer

1983	▪ Established in technical collaboration with Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland.
1985	▪ Production of 8.0"/5.25" Disks
1987	▪ Production of 3.5" Disks
1998	▪ ISO 9002 Certification
1999	▪ Production of CD-R, set up a 150-million unit capacity plant to manufacture Recordable Compact Disks (CD-Rs) and Recordable Digital Versatile Disks (DVD-Rs).
2000	▪ Production of CD-RW
2002	▪ Completely Integrated Manufacturing
2003	▪ Production of DVD-R and DVD-RW ▪ ISO Certification for all Facilities

	▪ Launch of 'Moserbaer' Brand in Indian Market ▪ Signed one of Largest Outsourcing Deals in Indian Manufacturing
2004	▪ 'Lightscribe' Deal with HP ▪ HP Deal for India and SAARC Region ▪ Contributing Member of Blu-Ray Disk Association
2005	▪ ISO 14001 & OHSAS 18001 certification for Moser Baer plants. ▪ Commencement of Phase III of Greater Noida Plant ▪ Announced Moser Baer Photovoltaic Ltd as it's wholly owned subsidiary ▪ Received status of SEZ developer from Govt. of India ▪ Announced a wholly owned subsidiary-Moser Baer SEZ ▪ Signed MoU with IIT, Delhi
2006	▪ The first company in the world to start volume shipments of HD DVD-R ▪ Signed Technology MoU with IT BHU ▪ Patented technology approved by the Blu-ray Disc Association ▪ In-house R&D Centre approved by Ministry of Science and Technology ▪ Launched USB Flash drives ▪ Forayed into entertainment space, enters Home Video market ▪ The company announced its foray into the Photovoltaic and Home Entertainment businesses.
2007	▪ Acquired OM&T BV - a Philips' optical technology and R&D subsidiary ▪ Announced start of trial run of solar photovoltaic cell production facility ▪ Set up the world's largest Thin Film Solar Fab ▪ Launched US$150 mn FCCBs ▪ Moser Baer Photo Voltaic announced commercial shipment of solar photovoltaic cells ▪ Moser Baer Photo Voltaic announced US$880 million strategic sourcing tie-up with REC Group ▪ Forayed into PC peripherals market: Launches Optical Disk Drives (ODDs), Headphones, Keyboards, Optical Mouse etc. ▪ The IT Peripherals and Consumer Electronics division was formed and launched Branded DVD Player
2008	▪ Moser Baer plans 600 MW Thin Film PV capacity with an estimated investment of over $ 1.5 bn ▪ Moser Baer Photo Voltaic announces strategic sourcing tie-up with LDK Solar

The company successfully transformed itself from a single business into a multi-technology business organization. The company articulated vision of touching lives through technology products and services encapsulates its commitment to embrace next generation technology to harness the immeasurable power of the knowledge capital to set new technology benchmarks.

The highlights of the company business strategy product wise and their operational objectives ranging from short to long term have been delineated below in the Table 5.15.

Table 5.15 Business strategy and operational objectives of Moser Baer

Business Strategy		
Optical	**PV business**	**Entertainment**
Short term • Increase global market share to 20 per cent • Leverage "first to market" and IP position in next generation Blue laser formats • Leverage existing R&D and technology capabilities in expanding product portfolio in storage (flash) • Double the contribution of value-added products (specials). **Medium term** • Consolidate global leadership position • Improve Return on Capital Employed (ROCE) and asset turnover. • Target "first to market" in near field and holographic technologies. **Long term** • Continued to be leader in media industry and to be a technology leader	**Short term** • Rapidly scale up capacities in crystalline silicon vertical. • Achieve best in class cost benchmarks on efficiency and yields. • Efficient sourcing strategy for raw material. • Commercialize new technologies • Hire key people to scale up these businesses. **Medium term** • Increase integration across the value chain. • Rapidly scale up the different technology verticals. • Emerge as one of the largest and most efficient manufacturer in world. **Long term** • Emerge as a leading, multi technology, integrated and efficient manufacturer in the global PV space	**Short term** • Acquire copyright/exclusive license of 40 per cent of mainstream films ever produced across all languages • Establish a strong pan-India distribution reach. • To have clear leadership / dominance in the segment. Selectively get into content creation. Selectively launch other content type through established channel. **Medium term** • To have clear leadership / dominance in the segment. • Selectively get into content creation. Selectively launch other content type through established channel. • Also evaluate alternate distribution platforms. **Long term** • Leader in creation and distribution of quality content spanning the entire entertainment & infotainment segments.
Operational Objectives		
• Further augment technological and cost leadership. • Scale up the contribution of value-added next generation products and penetrate markets with these products. • Continuously launch new innovative products for customers, in conjugation with new drive launches. • Drive working capital efficiencies and cash flows. • Develop strategic alliances for smooth raw material supplies.	• Commercialize silicon based 80 MW project on schedule and drive down cost. • Evolve an effective sourcing strategy. • Execute the projects for new technologies and get them to rapid and efficient commercialization. • Leverage existing core competencies to emerge as a large and the most efficient manufacturers of PV cells and Modules in the world. • Work closely with technology partners.	• Progressive launch more titles across the country in next six months. • Acquire more titles across different genre. • Further increase the distribution footprint.

5.4.2 Performance Indicators

Over the years, Moser Baer has been constantly searching for innovative ways of reducing costs while ensuring consistent high quality, flexibility and lean manufacturing. In this quest, the company has concentrated on doing different things as well as doing things differently. The company export close to 85% of total production annually, despite the remoteness between the production setup and the markets catered to, the company has developed and maintained its status as the lowest-cost producer of optical media in the world through 'creative engineering'. As a result, the company has emerged as the only company in the world to supply discs to all the major OEMs across the world. The snapshot of various financial performance indicators of the company and their trends has been discussed and presented in figure 5.5.

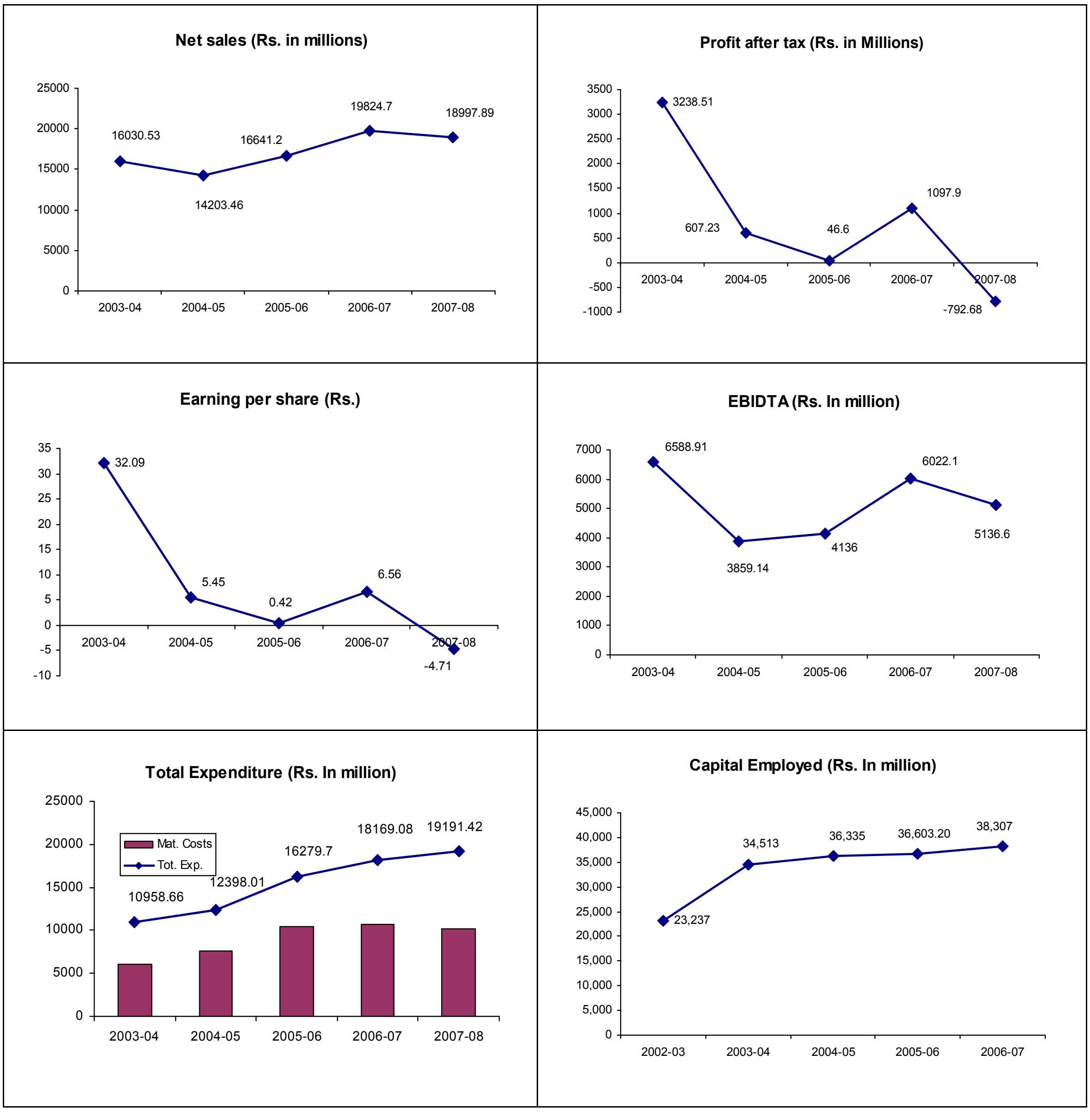


Figure 5.5 Performance indicators of Moser Baer

Net Sales: The net sales from operations were Rs. 16,030.53 mn in 2003-04 which was dipped by 11% to Rs. 14,203.49 mn in 2004-05 due to high pressure of price reduction in competitive market. In 2005-06, it rose by 17% to Rs. 16,641.2 mn. Following the same trend of rising sales, the company registered an increase of 19% in net sales to 19,824.7 mn. But again in 2007-08, the net sales dipped by 4% to Rs. 18,997.89 mn due to massive price reduction of high technology products.

Profit after Tax: The profit after tax (PAT) showed a large variation among the years of study. The PAT was Rs. 3238.51 mn in year 2003-04 which drastically slashed to Rs. 607.23 mn in year 2004-05 due to reduction in selling price of the media in a very competitive global market. The trend of diminishing PAT continued for the next year i.e. 2005-06 when it plunged to merely Rs. 46.6 mn. The year 2006-07 was a year of new hopes for Moserbaer, when its profits started rising and the PAT for the year 2006-07 worked out to be Rs. 1097.9 mn. But the year 2007-08 was the worst for the financial books of the company when it registered a net PAT of Rs. -702.68 mn i.e. a loss of Rs. 702.68 mn due to its product diversification and huge investments made in the other area like photovoltaic (PV) or entertainment. In Blank Optical Media, the production was disrupted in mid-year due to problems in the power plant. The issue was later fully resolved and capacity optimization was again achieved in the next quarters. While the Entertainment business achieved net break even in less than 12 months on operations, the PV business has also achieved significant revenue traction and is rapidly achieving scale. The aggressive volume-price strategy over the past years started to yield results with fringe players finding it hard to sustain themselves. Industry consolidation and increasing demand traction in Blu-Ray are the positive hues to an otherwise sedate industry environment in the near to medium term. Long term variables still remain healthy as need for storage and consumer demand continues to grow.

Earnings per Share: Earnings per share for 2004-05 was at Rs. 5.5, against Rs. 32.09 in 2003-04, a fall of 83.5%. The company generated gross cash of Rs. 3,427.7 million in 2004-05. Earnings per share for 2005-06 were at Rs. 0.42, against Rs. 5.45 in 2004-05. However, the company continues to generate strong gross cash flow of Rs. 3,214.3 million in 2005-06. Earnings per share for 2006-07 were Rs.6.56, against Rs. 0.42 in 2005-06. The company generated strong gross cash flow of Rs. 4,676.6 million in 2006-07. The EPS for 2007-08 worked out to be Rs. -4.71 for the reasons already explained above.

EBITDA: EBITDA fell to Rs. 3859 mn in 2004-05 from at Rs. 6,589 mn in 2003-04 due to falling prices of media in the very competitive global market. It then marginally grew to Rs. 4,136.0 mn during 2005-06. However, the company continues its efforts to gradually revert to normal levels of operational & financial performance, and EBITDA was impressively increased to during 2006-07. But EBITDA for 2007-08 fell to Rs. 5136.6 mn, primarily on account of pricing pressure being experienced in the global optical media market on account of the Philips licensing issue.

Total Expenditure: The total expenditure graph alongwith the material costs graph indicates that there is continuous rise in total expenditure and the raw material costs of the company. The company spent Rs. 10,958 mn during year 2003-04 and the expenditure for the year 2004-05 was increased by 13% to Rs. 12,398.01 mn. Further it was increased by about 31% to Rs. 16,279.7 mn in 2005-06. Then during 2006-07 it reached Rs. 18.169.08 showing an increase of 12%. Currently it increased by 5.6% to Rs. 19191.42 mn during year 2007-08

Total Capital Employed: The total capital employed in the business increased from Rs. 23,237 million in 2002-03 to Rs. 34,513 million in 2003-04, representing an increase of 48.5 percent. The company generated a healthy Return on Average Capital Employed during 2003-04. The total capital employed invested in the business increased to Rs. 36,335 million in 2004-05, an increase of 6.1 per cent. However, lower margins during the year 2004-05 resulted in reduction of Return on Average Capital Employed. While during 2005-06, the overall revenues of the company rose by over 28%, the total capital employed in the business increased marginally by 0.7% to Rs. 36,603.2 million in 2005-06. This implies an increase in asset utilization ratios. However, lower margins for the year resulted in further reduction of Return on Average Capital Employed. Again during 2006-07, the overall revenues of the company rose by over 19.8%, the total capital employed in the business increased marginally by 4.7% to Rs. 38,307 million in 2006- 07. This again implies an increase in asset utilization ratios and improving working capital management. Improving asset turnover and improving operating margins have resulted in a healthier Return on Average Capital Employed in 2006-07.

5.4.3 Manufacturing Capacity and Capabilities

Moser Baer manufactures products and provides services, which leverage its technology development and commercialization strengths to offer the best, value-enhanced and differentiated technology products and services to its global customer base. Improving operational efficiencies coupled with increasingly efficient & optimal use of assets - both fixed as well as working capital - is another positive trend in the company's performance.

The exploding global market in DVD and the growing disposable income levels within the domestic market presents immense scope ahead and the company is well positioned to exploit this emerging opportunity. The company leveraged its manufacturing base, expanded capacities, customer relationship and the explosive growth to significantly enhance its global share and not merely retain, but further improve its leadership position within the industry. In addition, the intend to utilize its core mass manufacturing capabilities, especially in high technology process driven industries to capitalize on the growing global trend towards outsourcing.

Storage Devices: In the Indian market, Moser Baer made its foray into the burgeoning domestic optical storage market with the launch of the `Moser Baer' label in 2003. The company has blazed a new trial by introducing technologically innovative and truly world-class product in the Indian market. Moser Baer's new range of Gold and Platinum CD-Rs have been developed keeping native conditions in mind in terms of enhanced durability and resistance to both environmental and human-induced hazards. The company manufactures the entire spectrum of optical storage media products including recordable compact discs, rewritable compact discs, recordable digital versatile discs, rewritable digital versatile discs and blue laser discs. Moser Baer's products adhere to the most stringent process and quality standards. The company employs over 7,500 people and has an annual production capacity of over 3 billion units.

Photovoltaic: The company also aims to distinguish itself as a significant player in the global photovoltaic (PV) market by leveraging its high-volume manufacturing expertise and planned investments of nearly US$ 3.2 billion in research, development and manufacturing of products dedicated to generating solar power.

Entertainment Project: The company is the first to offer home videos in every popular language of India and it is today India's largest Home Entertainment Company. Moser Baer Entertainment has acquired the rights for close to 10,000 titles in all the popular languages and has already released close to 3,000 of them in the market. This move has taken advantage of Moser Baer's established production capability and a well-developed national distribution network. This business has also acted as a lever to de-commoditize the blank optical media business given its higher value addition and high returns on invested capital. During the year the company did a phased national launch of its video content on DVD and Video CD (VCD) formats using its proprietary and patented technology with enhanced quality and significantly reduced cost. This has enabled the company to revolutionize the quality-price parity and offer unprecedented value for the consumers in Indian market.

5.4.4 Role of Technology

Moser Baer has been quite successful in enhancing its business performance through adoption of new technologies, most of which have been developed in-house by the R&D division of the company. The company has achieved a unique technology & IP position in the blu-ray format through its own pioneering work and acquisition of OM&T (a former R&D subsidiary of Philips BV) - marking the transition of the company from a technology innovator to a technology developer. The company realizes that PV markets have different needs and emerging technologies have to be developed today to realize the world's future energy needs. It has already announced investments in a mix of currently available and emerging technologies as follows:

- A first of its kind 80 MW, state-of-the-art, fully automated in-line crystalline silicon cell manufacturing facility - 40 MW already in productions - this will be scaled up to 240 MW.
- A 40 MW module manufacturing facility with expansion plans to scale it up to 200 MW.
- A 200 MW thin film module plant, capable of producing the world's largest non-flexible thin film modules, is under construction.
- A high concentrator photovoltaic (CPV) module manufacturing facility and multi-million dollar investments in a US-based company - Solfocus, the developer of the CPV technology in partnership with the world renowned Palo Alto Research Center (PARC), California.
- A significant equity stake in Solaria, a US-based technology company that has developed a unique form of low-concentration solar PV technology.
- A significant minority stake in Stion Corporation, a nanostructures development company based in the Silicon Valley, California, for producing extremely low-cost solar power generating surfaces.

- Acquisition of 40% equity stake in Solarvaiue, Proizvodnja d.d, a solar grade silicon production facility in Slovenia, to provide access and assurance of supply to low-cost solar grade silicon.
- An R&D centre dedicated for the improvement and rapid commercialization of solar technology products.

In addition to the above, the company has invested in strategic partnerships involving the entire value chain, particularly for strategic sources such as silicon ingots and wafers, glass, etc. through short-term and long-term supply agreements.

As technology plays a bigger role in the ability to offer a complete basket of products to its customers, the company efforts towards technology adoption, innovation and R & D along with the benefits derived during the recent past has been presented in the Table 5.16.

Table 5.16 Role of technology, innovation and R&D at Moser Baer

EFFORTS MADE TOWARDS TECHNOLOGY ADOPTION, INNOVATION AND R & D	BENEFITS DERIVED FROM TECHNOLOGY ADOPTION, INNOVATION AND R & D EFFORTS
• The company has entered into agreements to acquire technology and the right to use technology belonging to other third party companies. • A number of agreements were completed to acquire technology belonging to companies whose R&D efforts have been complementary to the technology development program. This technology has been successfully incorporated into some of the company's products and an ongoing effort is being made to improve the utilization of this technology and produce newer innovative products based on this technology. • The company is a part of many international forums and R&D initiatives that are dedicated to the development of future formats like Light Scribe technology, HD DVD and Blu-ray. Such participative activities have significantly enhanced the image of the company as an individual entity and India as a whole in the mind of the international community. • Equipments like ODU 1000, Spectro photometer (covering wavelength range from 190 to 1100 nm), DSC for crystallization studies, high magnification microscope, LCMS (Liquid chromatograph mass spectro meter) for dye studies have been a part of technology adopted in 2006.	The specific areas in which the company carried out R&D and the benefits derived as a result thereof are as follows: 1) Development of following new modified formats: • BDRE (Rewritable) high density optical media • BDR H2L 1x-2x • BDR H2L 1x-4x • BDR H2L 8x • HD DVD single layer media and double layer media (first to market) 2) An entirely new design of co-sputtering machine has been developed in collaboration with IIT, Delhi. 3) Development of following new products: • DVD+RW 8x • DVD-RW 1x-2x Mini RW • CDR/DVD R Light Scribe version 1.2 • Special Printable Process 4) The set up of R&D lab with the following features: • DVD and Blu-ray disc test set up • Format verification set up • Playability test set up • LCMS (Liquid chromatograph mass spectro meter) for dye studies. 5) As a result of the various R&D activities undertaken by the company, it will gain edge over other media manufacturers.

IT peripherals and Consumer Electronics: Moser Baer has entered into IT Peripherals (Solid State) and Consumer Electronics. Branded USB drives, Memory Cards, DVD writers, Mouse, Headphones, Keyboards and DVD players are now available in the market. In the Consumer Electronics arena, the company has also leveraged its equity and brand image and unveils a product range with medium-to-high end positioning.

The company exports majority of its products to international markets, thus the advanced technology is the lifeline of Moser Baer. The products to be exported have to meet international requirements, which are otherwise very stringent with regard to reliability, safety and pollution.

Moser Baer strongly participates in inter-company groups and networks consisting of other Original Equipment Manufacturers (OEMs). Moser Baer works on Japanese concepts and does not believe in rework and remanufacturing. Quality standards and procedures are followed piously. It seeks advice to a large extent from its customers in order to improve its products and thus the voice of customers has got a good place in this company.

5.4.5 Role of Sourcing Practices

Whether it is designing new grooves, looking for alternate sourcing options, working with vendors to improve machinery and lines or maximizing utilization of space while designing lines, the company keeps pursuing the best combination and permutations to derive substantial tangible benefits such as lower cycle-time, cost effectiveness, higher productivity, higher flexibility and lower wastage. The company has successfully managed the demand -supply imbalances in the market environment through the effective use of sourcing practices. The company is working on long-term strategic sourcing arrangements with key raw material suppliers, which are expected to significantly mitigate the risk of demand-supply imbalances in critical raw material, which in course severely impact operations.

On the manufacturing front, through innovative engineering and intelligent sourcing the company have continuously been able to cut cycle time and costs to affirm its position as one of the lowest cost and highest quality producers in the industry. The company has taken a step forward for technology collaborations and sourcing arrangements with global technology companies in emerging areas. The company has entered into a strategic partnership with Pyramid Saimira Theatre for home video marketing and retailing.

***Developments in the PV business**:* In addition to the target of being one of the most efficient solar cell manufacturers, the company also put in place an efficient silicon sourcing strategy to adequately address current demand supply imbalances in silicon availability. The company is working towards closing medium to long term sourcing agreements for the project. In line with this strategy, the company announced the strategic sourcing tie-up with Deutsche Solar, a leading global silicon wafer manufacturer, for the supply of silicon wafers. This strategic stake has helped the company to secure long-term supplies of solar grade silicon wafer at competitive prices.

Sourcing of key inputs: Polycarbonate for optical media and polysilicon for photo voltaic are critical key raw material. These commodities are influenced by a variety of factors, including crude prices, respective demand-supply balance, etc. Any sharp increase in prices of these commodities or demand-supply imbalances could adversely impact business. The company is working on strategic sourcing agreements, including investments into production facilities, for critical raw materials. This should ease the impact of any pricing volatility and improve production planning.

Collaboration with Academia: The company is amongst a handful of companies that have tie-ups with leading technology institutes like the Indian Institute of Technology, Delhi and Banaras Hindu University (BHU), Varanasi. These institutions contain a vast pool of highly talented scientists and with collaborative activities like these breakthroughs research can be achieved. The tie-up with IIT is primarily to work jointly in the frontier areas of thin film sputtering technology suitable for optical data storage devices whereas in the tie-up with BHU, the emphasis has been on alternate materials development.

Market development: **T**he company has been evaluating various business opportunities for diversification and broadening its product portfolio. With an eye to expand the existing market, the company has started focusing on value-added products to drive an expansion in margins. As the company sells predominantly to OEM customers, who source their products on a global basis, individual market changes have a lesser impact on the company's operations. The share of outsourced volume from an OEM customer has a greater impact on the company's operations and, hence the company's focus is to increase the share of a customer outsourcing its requirements.

5.4.6 Social and Environment Aspects

At Moser Baer, the Corporate Social Responsibility (CSR) is the way to conduct business that achieves a balance or integration of economic, environmental and social imperatives while at the same time addressing customers' expectations. The company affirms its commitment of seamless integration of marketplace, workplace, and environment and community concerns with business operations. The company uses CSR as an integral business process in order to support sustainable development and constantly endeavors to be a good corporate citizen and enhance its performance on the triple bottom line.

Whilst being committed to excellence and total customer satisfaction through teamwork, ceaseless innovation and timely delivery of quality products of international standards, the company recognizes its responsibilities towards social and environmental dimensions of the business and thus aims to visibly play a leading role within the spheres of influence. The company strives to be a leader while continuing its business in a socially and environmentally responsible manner. The company commitment to contribute to nation building measures through improving quality of life of to its workforce, their families and the communities of the area exists.

5.4.7 SWOT (Strength, Weakness, Opportunity and Threats) Analysis

On the basis of the study carried out in Moser Baer, SWOT analysis has been done and presented in Table 5.17.

Table 5.17 SWOT analysis of Moser Baer

Strengths	Weaknesses
• Lower capital investment compared to industry standards and high process efficiencies enables global cost leadership. • Integrated & Flexible manufacturing facility enables adapting to changing market dynamics. • Cutting edge R&D infrastructure enables development of superior technology products and faster commercialization of the same to emerge "first to market". • Involving suppliers in long term strategic sourcing aspects for critical material supply. • Present in multiple technologies within each business segment. • Excellent project management, large-scale production skills enabling faster technology commercialization. • Emerging from a technology innovator to technology developer. • Presence in multiple businesses having high growth and return on invested capital.	• Key raw materials in the business are commodities, hence exposed to price fluctuations. • As the new businesses are in investment phase, they will require large investments of funds, manpower and resources in the short term. • Internal control and information systems need to be strengthened to meet the requirements of a multi businesses organization handling large number of product variants across segments.

Opportunities	Threats
• A first to market and unique IP position in the next generation Blu Laser based formats provides a significant competitive edge and growth opportunity as demand for these formats grows to over 1.7 billion discs by 2009. • The company has emerged as the second largest player for DVDR/RW formats in the world - a segment which is to grow tremendously. • **Domestic market:** India is one of the fastest growing markets or optical media. The company is well positioned to dominate this captive market. • **Solar Photo Voltaic business:** Increasing reliance on clean energy and falling PV system costs are set to grow global demand by over five times by 2010 which presents Moser Baer with an exciting growth opportunity. • **Home entertainment business:** This business represents an excellent opportunity to leverage proprietary technology, enable the setting of new cost benchmarks and de-commoditizing of the blank optic media business by higher value addition.	• **Alternate technologies:** Threat of technology obsolescence and alternate technologies is a constant in the optical and PV space. • **Prices of key inputs:** Polycarbonate for optical media and polysilicon for photo Voltaic are critical key raw material. These commodities are influenced by a variety of factors, including crude prices, respective demand-supply balance, etc. • **Anti dumping and anti-subsidy / government policies** • **Fall in product prices:** As products move into the mature phase in their life-cycle, they start to emulate commodity- type characteristics. Also, optical media industry has relatively high capital intensity; hence a sharp fall in prices could severely impact overall returns. • **Emerging delivery platforms in entertainment segment**: The introduction of video-on-demand, IP TV, pay per view services, etc, which enable the customers to select and watch movies at their convenience could compete with the physical distribution of home video.

5.4.8 Status of Manufacturing Flexibility

Moser Baer is a global technology leader that understands people's digital data storage requirements. The company leverages its competencies in base material engineering, thin film coating and precision sputtering to lead the technology development curve. With a capacity to manufacture over 3 billion discs per annum and a market reach in over 82 countries, the company has the technological prowess to manufacture the entire range of optical media ranging from 700 MB CDs to over 50 GB blue laser based discs.

The company has transformed its position to technology supplier by patenting its technology and products, reduced inefficiencies in the entire supply chain. Significant investment in newer technologies has helped the company to attain flexibility dimensions in terms of volume, modification and delivery flexibility over a distinct range. The company has established its facilities to become a system supplier to its OEM apart from manufacturing aspects only. The company has developed the technology at its own and also adopted from its alliance partners to reduce the lead-time to new product introduction even before the demand exists, thus become the technology innovators.

The company has introduced the process improvements in the manufacturing system, produce large number of product categories and manage volume changes effectively for facilitating the achievement of manufacturing flexibility at the tactical level**.** The company has further enhanced its competency to attain rapid delivery of innovative and customized products. The manufacturing system can be expanded easily when needed in the long run and expansions do not affect the quality levels of output.

Volume flexibility: Driven by a confluence of factors - including continuing consolidation of capacity, growth in consumer demand and softening of input costs, the company consolidated and maintained its position as the second largest manufacturer of optical storage media in the world. The company has handled the rapidly increasing production volumes and varied level of production volume quickly. However, operating at different production volumes in a manufacturing system has moderate impact on the profitability of the company.

The company has developed strategic alliance for smooth raw material and critical component supplies. Long term strategic sourcing arrangements with key raw material suppliers has been established to significantly mitigate the risk of demand-supply imbalances, which in turn help the company to achieve volume flexibility. The company has increased its blank optical media capacity from 2.8 billion discs per annum to 3.4 billion discs per annum in 2006-07 through an efficient mix of new capacity and opportunistic acquisition of couple of distressed capacities.

Moser Baer is the first company in the world to commercially ship HD DVD format to its top tier customer base. Increasing supply of Blue laser optical pick up heads and emergence of drives which can read/write both HD DVD and Blu-ray formats are significant positive developments which should provide further impetus to growth of these formats. Moser Baer Photo Voltaic (MBPV) has started commercial production of its first phase of crystalline silicon capacity and rapidly achieves scale by ramping up capacity to over 200MW.

Modification flexibility: The company operates in an industry where technology trends are constantly changing. For mitigating the risk, the company has been evaluating various business opportunities for diversification and broadening its product portfolio. With an eye to expand the existing market, the company has started focusing on value-added modified products to drive an increase in delivery and margins. The company has buildup a capacity of producing minor alterations in product design to meet customization quickly and efficiently, except with moderate transition penalties. Reengineering the manufacturing facilities in terms of de bottlenecking the existing production lines and addition of new lines has further improve the status of modification flexibility.

The company also enlarged its existing product range and offer many variants along with cost reduction through the value analysis/value engineering and development of cross-organizational teams with its subsidiary companies and vendors.

Delivery flexibility: Moser Baer is a global leader in the development, manufacture and supply of technology products across the globe and is fast transforming into a multi-business technology group. The company has introduced the customized products for new market creation periodically in domestic and international markets and handled rapid delivery of innovative products satisfactorily. It includes double layer storage media formats, mini DVD recordable and re-writable discs and Gold Media. The company launched an in house developed "Aqua Shield" media, a niche product for the European market. The company was also the first company in the world to commercially ship next generation HD DVDR format. The acquisition of OM&T (an erstwhile subsidiary of Philips) has significantly strengthened the company's position of being a frontrunner in the next generation Blu-ray format given OM&T's pioneering work and manufacturing expertise in the Blu-ray disc technology.

Though, the customized products for new market creation are handled with ease except the implementation of “cost target approach” that makes the process more stringent, complex and competitive in nature. With an eye to expand the existing market, the company has started focusing on value-added products which reflects the commitment to move up the value chain in terms of giving premium & value added products to its customers. The company's strategy is to transform Moser Baer into a technology developer and innovator from a technology recipient. The strong R&D has enabled the development of high value products, which will build the differentiation barriers in the long term. As consumption evolves from analogue to digital technology, it is prompting legacy recordings to migrate to new media. In line with the long-term strategy of creating multiple synergistic businesses, the company made its maiden foray into the entertainment industry through the Indian home video market. This business is identified as an important value enhancing, forward integration initiative to the optical media business. It has de-commoditize the blank optical media business due to the higher value addition to its products. The entertainment business is significantly less capital intensive compared to optical media business and hascontributed to improving the overall returns on invested capital. Additionally, the company also entered the exciting global photovoltaic industry, which is growing at a rapid pace.

Overall, the status of tactical and strategic level manufacturing flexibilities in the context of the study for MSIL has been graphically revealed in figure 5.6.

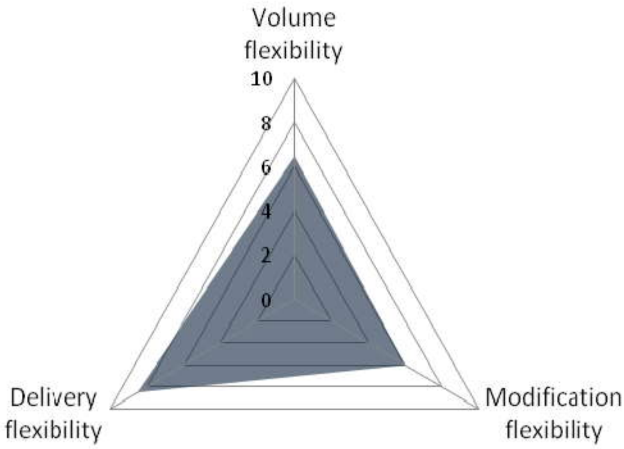


Figure 5.6 Status of manufacturing flexibility at Moser Baer

5.4.9 Relative Performance of Technology and Sourcing Practices

Investment in manufacturing, design and infrastructural technology and localized R&D efforts has helped the company to maintain and further increase its market share in the highly competitive and turbulent market environment as leading OEM and tier-1 supplier. At the same time, supplier involvement at strategic level helps in pacing the rate of growth for the company. The relative impact of adopting new technology in comparison with sourcing practices for achievement of different business objectives has been presented in the Table 5.18.

Table 5.18 Impact of adopting new technology and sourcing practices at Moser Baer

		Impact of adopting new technology on performance objectives	**Impact of adopting sourcing practices on performance objectives**
1. PRODUCT QUALITY			
i.	Performance of products	+++++	+++
ii.	Features of products	+++++	+++
2. DELIVERY			
i.	Speed of delivery	+++++	++++
ii.	Number of customized product offered	+++++	+++
iii.	New product lead time	+++++	+++

3. FLEXIBILITY			
i.	Variety of modified products	+++++	+++
ii.	Delivery of innovative products	+++++	+++
iii.	Capacity to change product volume	+++++	++++
4. COST			
i.	Product cost	+++	+++
ii.	Cost of future product innovations	++++	+++
5. EFFECT ON MARKET SHARE		++++	+++
6. NET PROFIT		++++	+++
7. OVERALL PERFORMANCE		**HIGHLY SATISFIED**	**REMAINED THE SAME**
(+) significantly decreased, (++) moderately decreased, (+++) remained the same, (++++), moderately increased, (+++++) significantly increased.			

The level of dependency on different sourcing practices for achieving the various manufacturing flexibilities is presented in Table 5.19.

The role of manufacturing and infrastructural technology and supplier involvement in managing capacity fluctuations has come out be important factor for achieving volume flexibility. The company has invested in the further development of existing technologies and innovation of new ones at its own or through strategic alliances, for modifying the existing product range and delivering the new products. The company develops a technology strategy, which includes a framework with priorities and an action plan. Also, the company is building core capabilities in some critical areas and exploiting these to the maximum extent. The company is forming and exploiting linkages with networks of technology suppliers and others involved in the technology.

Table 5.19 Level of dependency on technology and sourcing practices

Sourcing Practice →	**OUTSOURCING OF MANUFACTURING**	**STRATEGIC SOURCING** ***(Outsourcing the in-house core competencies)***	**ADOPTION OF NEW TECHNOLOGY**
VOLUME FLEXIBILITY	+++	++++ ***(for the key raw material and critical components)***	++++
MODIFICATION FLEXIBILITY	++	+++	++++ ***(technology up gradation through local R&D)***
DELIVERY FLEXIBILITY	++	+++ ***(tie up with the technology collaborators and innovators)***	+++++ ***(Adoption and development of base technologies)***
+ - Not dependent, ++ - Least dependent, +++ -Moderately dependent, ++++ - Highly dependent, +++++ – Fully dependent			

The company is working on strategic sourcing agreements, including investments into production facilities, for critical raw materials. This should ease the impact of any pricing volatility and improve production planning. More recently, MBPV also announced acquisition of a 40% strategic equity stake in Slovenia-based Solarvalue Proizvodnja d.d. This strategic investment ensures stable and cost effective supply of solar grade silicon wafers over the long term.

The company also entered into a strategic tie-up with Deutsche Solar for sourcing silicon wafers in line with its strategy to meet its silicon requirements in an efficient and cost effective method.

5.4.10 SAP Analysis at Moser Baer

Table 5.20 shows the SAP analysis at Moser Baer while LAP synthesis is described.

Table 5.20 SAP analysis at Moser Baer

Situation	Process
• Technical collaboration with Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland. • Lowest-cost producer of optical media in the world through 'creative engineering'. • Leadership in technology, innovation and R&D for increased localization. • Production capacity of the company has increased over the years. • State-of-the-art manufacturing facilities that adhere to the most stringent process and quality standards. • An R&D centre dedicated for the improvement and rapid commercialization of solar technology products. • Invested in strategic partnerships involving the entire value chain with OEMs and tier-2 suppliers. • Long-term strategic sourcing arrangements with key raw material suppliers. • Technology collaborations and sourcing arrangements with global technology companies in emerging areas. • Company commitment to be a leader while continuing its business in a socially and environmentally responsible manner. • Entertainment project act as a lever to de-commoditize the blank optical media business given its higher value addition and high returns on invested capital.	***Technological Aspects*** • Technical collaboration with world leaders has helped in manufacturing of world-class products. • Increasing the customer's base by the continuous introduction of photovoltaic, entertainment and consumer electronics project. • Execution of the projects for new technologies and get them to rapid and efficient commercialization. • Reducing the product development time through global and local research and development facilities. • Saving costs through technology and efficient working including intelligent engineering concept. • Extensively using in-house capabilities for making new technology cost-effective • Official visit foreign countries to get new ideas to develop new technology in-house. • The company redesigns its production system to some extent to achieve satisfactory ergonomic safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation. ***Sourcing Aspects*** • Developed strategic alliance for smooth raw material and critical component supplies.

<table>
<tr><th>Actors</th><td rowspan="2">Long term strategic sourcing arrangements with key raw material suppliers; significantly mitigate the risk of demand-supply imbalances.
Through innovative engineering and intelligent sourcing, the company have continuously been able to cut cycle time and costs to affirm its position as one of the lowest cost and highest quality producers in the industry.
The company is forming and exploiting linkages with networks of technology suppliers and others involved in technology.
Encouraging vendors to offer suggestions for technological improvements and price reduction of the components.
Increased integration of value chain across OEMs and tier -2 suppliers has helped in modifying and introducing new products early and efficiently.</td></tr>
<tr><td>Chairman, Board of Directors as the key decision maker.
Technical collaboration with Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland
Skilled, trained and flexible work force, eminent academia scientists and entire value chain as key knowledge provider.
Reputed OEMs as demanding customers.
Strategic partners and vendors.</td></tr>
</table>

5.4.11 Learning Issues

Based on the detailed study and analysis of the initiatives taken by Moser Baer to attain global market share, flexibility, quality, cost reduction and productivity following learning issues have emerged.

Business initiatives: Recognizing the potential of technology and innovation, Moser Baer has continuously harnessed the power of its knowledge capital. This together with its commitment to be at the cutting edge of technology has only strengthened its ability to set new technology benchmarks that have the power to impact and touch lives.

- Moser Baer ranks as one of the world's largest and lowest-cost optical media manufacturer helping consumers safely, securely and cost efficiently stores their digital data. The company has leveraged its robust R&D strengths to develop a new generation of storage devices, which can archive critical and sensitive data for years and has also emerged as the first to market the next generation of storage formats such as Blu-ray Discs (BD) and HD DVD.
- Moser Baer has extended its core competencies in an endeavor to provide a clear roadmap to bring down solar electricity cost down to conventional energy price points. The photovoltiac initiatives have the potential to enable a faster and cost-effective transition to the renewable solar energy market and in turn directly or indirectly impact the lives of people across the globe.
- Looking ahead, Moser Baer intends to add features to the existing data storage products, combine them with in-house technological capabilities and cater to the

aspirations of billions of Indian movie fans. The company has already launched licensed movies in the VCD/DVD formats at unbelievable price points and with unmatched quality, an unprecedented initiative in the country.

- Seamlessly future proofing capital investments assures evolutionary capabilities of manufacturing infrastructure.

Technology aspects: Moser Baer is committed to continuously leverage its technology platform, rapid commercialization abilities to offer highly efficient, technologically advanced, low cost optical storage media that promises to 'touch lives' of people across the globe. The company has been able to transition itself into a technology leadership position.

- The company is investing appreciable amount in new machinery and equipment and R&D to keep itself updated with the latest technology.
- Strong technical support from its own R&D division, Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland helps it in grabbing the large market share.
- Develop / acquire new technologies covering all of the operations and processes of the company.
- The company is building core capabilities in some critical area and exploiting these to the maximum extent.
- The company laid considerable emphasis on VA/VE to cut down costs.
- Acquisitions of pioneering companies in optical media R&D have enhanced the leadership position of Moser Baer in the next generation optical format race.
- The company adopts new technology covering all processes & operations. Moser Baer does extensive analyses based on the trends of the past years before going in for new technology. It goes for economic viability study for adopting new technology and analyses quantitative and qualitative effects in details.

Sourcing aspects: The company has a long term strategic alliance with the key suppliers for providing technology and critical components and raw materials. Sharp commodity cycles and demand-supply imbalances in critical components and raw material can severely impact operations. The company is working on long-term strategic sourcing arrangements with key components and raw material suppliers; which are expected to significantly mitigate this risk.

- Longstanding strategic partnerships with key technology providers, allows the company to access new technologies.
- Adopt the new technology from alliance partners to reduce the lead-time to new product introduction and further localize it to suit market conditions with in house R&D efforts.
- MBPV announced the strategic sourcing tie-up with Deutsche Solar, a 100 per cent subsidiary of Deutsche Solar AG, one of the largest global producers of silicon wafers.
- Entered into a strategic partnership with Pyramid Saimira Theatre for home video marketing and retailing.
- The company is working on strategic sourcing agreements, including investments into production facilities, for critical components and raw materials. This should ease the impact of any pricing volatility and improve production planning.
- Cooperative links with all major hardware suppliers facilitates drive/media compatibility.
- Technology collaborations and sourcing arrangements with global technology companies in emerging areas.
- The company derives a significant part of its revenues from international markets. These have seen a growing protectionist attitude and a tendency by some local governments to use antidumping and trade protection tools to provide protection to local businesses.
- Company having flexibility for either acquiring or developing new technology for future projects.
- The company is forming and exploiting linkages with networks of technology suppliers and others involved in technology.

Manufacturing flexibility: The organization relies on adoption, adaptation and further development of manufacturing technology and infrastructure in house to achieve volume, modification and delivery flexibility. It is learnt that with large product mix, a company can make use of its facilities optimally.

- The involvement of vendors in providing capacity support helped organization in achieving volume flexibility.

- Early involvement of suppliers for design and development and supplier competencies has impacted the achievement of delivery flexibility moderately. The significant use of technological and sourcing aspects helps the company to achieve the delivery flexibility leading to the introduction of new products with minimal lead-time.
- The augmentation of facility with new technology and the specialized technological capabilities of supplier(s) have helped the organization to achieve the modification flexibility.

5.4.12 Action Suggested

The initiatives taken up at Moser Baer depict the capability of organization to become the market leader in terms of new and high tech products. The optimum use of facilities, adoption of new technology, deployment of various quality management techniques, increased effort in R&D facility has helped the company to achieve flexibility and reduce cost, customer rejections and waste. The company must increase their focus on import substitution and enhance capabilities for design and modification at micro level. For further cost cutting, more systematic changes are required in the company. The role of suppliers' needs to be further explored to achieve flexibility in the manufacturing system and business excellence.

5.4.13 Performance Expected

Moser Baer has been quite successful in achieving manufacturing flexibility through adoption of new technologies, most of which have been developed in house by the R&D division of the company. The company is doing extremely well on all fronts. The role of strategic sourcing is also bearing fruits for the company in long run. The company has the flexibility to try different options of change mechanism to achieve its objectives of improved product quality, flexibility, productivity and competitiveness. The company has the product flexibility to meet the varying demands of OEMs and process flexibility to manufacture different models on the same production lines. The company has established a very strong R&D base to provide the latest technology products to its valued customers.

Major factors of importance for achieving manufacturing flexibility at tactical and strategic level that need to be closely monitored in this case with equal importance are continual adoption, adaptation and further development of manufacturing technology and use of various sourcing practices, including early involvement of supplier for developing new or modified component.

5.5 Punjab Tractors Limited (PTL)

Punjab Tractors is a leading tractor manufacturer in the country with a pan- India presence. The company is in the business of manufacturing and selling tractors with a view to satisfy customers having farm mechanization and other commercial applications needs. Besides this, forklifts are manufactured and sold to industrial customers, to meet their material handling equipment requirements.

Punjab Tractors Ltd. (PTL) was promoted as the country's first large scale, totally indigenous project to commercialize India's first tractor in 1970, by Government of Punjab. The company successfully launched its first commercial tractor under the brand Swaraj in April 1974. Swaraj 724 (26.5 HP) was the first tractor model launched by the company. In the last thirty-four years, the company has sold more than six and half lakh tractors. The company has developed ten tractor models with more than a hundred variants, during this period. The popular models sold under SWARAJ brand are: SWARAJ 744; SWARAJ 735; SWARAJ 855; SWARAJ 978; SWARAJ 834; SWARAJ 939; SWARAJ 733; SWARAJ 724 and SWARAJ 722. It has an extensive dealership network with more than five hundred and fifty dealers. The company has also expanded its presence in the overseas markets including select African and SAARC nations. PTL is also the largest producer of Harvester Combines in the organized sector of India.

The company endeavors to achieve a high level of customer satisfaction by also providing prompt and reliable after sales service. However, manufacturing costs of tractors at PTL has increased steadily with the increasing input costs, in result witnessed a tough job for maintaining its position in the farm equipment sector.

5.5.1 Business Strategy and Initiatives

In the first phase, 1974-97, the company chooses technology as the main driver to capture the market share. New models were introduced, and amendments made in the existing models. Tendency has been to manufacture all the ranges of tractors to give a competition to other brands. However, in the second phase, 1998 onwards, emphasis has shifted from manufacturing technology to infrastructural technology and systems.

Due to repeated draughts, and the industrial recession in the recent years, the company has diverted its attention to reduce the cost and developed local vendors, decreased inventory level and increased customer focus. Considering the number of players in the market and their capabilities, the company has found it difficult to retain its market positions. But having regard to the foregoing, Punjab Tractors has sustained a disciplined growth in its core tractor business and is well positioned on the basis of its competitive strengths: product range, broad geographical spread of dealer outreach, quality of service support and all India product acceptability. Development of a global product portfolio for meeting specific needs of new geographic market and customer segments has also received a priority attention.

Parallel corporate thrust has been towards further enhancement of the company's strong and well-demonstrated commitment towards continuous improvement in asset utilization, process efficiencies, supply chain, and cost management. Owing to various business initiatives in the recent past, the company has improved its competitive position in terms of product quality, new product introductions and product features and varieties, but find difficult to achieve flexibility competence.

Actis, a private equity firm acquired 29% of Punjab Tractors in mid-2003 from the Punjab Government. In March 2007, Mahindra &Mahindra, the fourth largest company in the tractor market segment bought a controlling 43% stake in Punjab Tractors Ltd. that has reportedly increase M&M's share in the domestic tractor market from just over 30% to nearly 40%. The 43% stake in Punjab Tractors includes the 29% owned by Actis and 14.2% by the Delhi-based Burman family. In July 2007, Mahindra upped its share in Punjab to 64.6%.

Punjab Tractors Limited (PTL), has regained the number one brand position in Punjab after a gap of six years in 2008 after the takeover of Punjab Tractors management by the new team as all out efforts started to bring back vibrancy in the organization. These efforts resulted in a massive improvement in the performance overall. Despite the prevailing volatile market situation, the company sustained its competitiveness position mainly due to cost reduction exercises, value-engineering efforts, better buying practices and sourcing synergy with Mahindra & Mahindra Ltd.

The snapshot of the achieved milestone and the business decisions are delineated and presented in the Table 5.21.

Table 5.21Milestones of Punjab Tractors Limited (PTL)

1965	• Govt. of India's research institute (CMERI) at Durgapur initiates design and development of SWARAJ tractor based on indigenous know-how.
1970	• Punjab Govt. through PSIDC acquires SWARAJ tractor's design from CMERI and establishes Punjab Tractors Ltd. (PTL) for its commercialization.
1971-73	• PTL sets up SWARAJ Project for 5,000 tractors per annum at a capital outlay of Rs. 37.0 million with an equity base of Rs 11.0 million.
1974	• Swaraj 724 (26.5 HP) tractor commercially introduced.
1975	• 2nd tractor model SWARAJ 735(39 HP) developed by own R&D, commercially introduced.
1978	• 3rd Tractor model SWARAJ 720 (19.5 HP) developed by own R&D, commercially introduced. • Maiden equity divided declared.
1980	• Guided by social concerns and responsibility, PTL takes over PSIDC's sick scooters unit - Punjab Scooters Ltd. (subsequently renamed as SWARAJ Automotives Ltd.) • India's first Self propelled Harvester Combine - SWARAJ 8100 developed by own R&D, commercially introduced. • SWARAJ Foundry Division set up in backward area.
1981	• Issue of maiden Bonus Shares (2:5), paid-up equity moves to Rs 15.4 million.
1983	• 4th Tractor Model - SWARAJ 855 (55 HP) developed by own R&D, commercially introduced. • Expansion of annual capacity to 12,000 tractors per annum at Plant 1.
1984	• SWARAJ MAZDA Ltd. promoted in technical and financial collaboration with Mazda Motor Corpn. & Sumitomo Corp. Japan for manufacture of Light Commercial Vehicles. • PTL's equity participation is Rs. 30.4 million (29%) and that of Mazda and Sumitomo's Rs. 27.0 million (26%).
1985	• SWARAJ Industrial Forklift Trucks developed by own R&D, commercially introduced.
1986	• SWARAJ ENGINES Ltd. promoted in technical and financial collaboration with Kirloskar Oil Engines Ltd.(KOEL) for manufacture of diesel engines. • PTL's equity participation is Rs. 6.9 million (33%) and that of KOEL's Rs 3.6 million (17%).
1989	• 1st Right Issue (1:1) at a premium of Rs 50/- per share (plus reservation of 200 Shares per employee) paid up equity moves to Rs 31.6 million.
1993	• Annual tractor capacity expanded to 24,000 per annum at Plant 1.
1995	• Setup of tractor Plant II at Village Chappercheri with annual capacity of 12,000 per annum.
1998	• Commencement of expansion to 60,000 tractors (30,000 at each plant). Capital outlay of Rs 1000 million, funded mainly through internal accruals.
1999	• 5th and 6th tractor models - SWARAJ 733 (34 HP) & SWARAJ 744 (48 HP) developed by own R&D, commercially introduced.
2000	• Expansion of annual tractor capacity to 60,000 completed. • The company plans to expand capacity further at its existing plants to 72,000 units and add another Greenfield plant with a capacity of 30,000 units. The capital expenditure of Rs 300 crore is to be financed through internal accruals.
2001	• PTL won National Championship trophy in competition organized by All India

	Management Association (AIMA) for young managers. • Economic times and Boston Consulting Group selects PTL as one of the India's finest 10 companies out of Economic times top 500 Companies.
2002	• Cumulative tractor sales cross 5,00,000.
2003	• PSIDC's disinvestments of its entire Equity holding (23.49%) in PTL in favor of CDC Financial Services (Mauritius) Ltd. With this, total holding of CDC & its associates in PTL stands at 28.48%.
2004	• 7th & 8th tractor models - Swaraj 939 (41 HP) & Swaraj 834 (34 HP) developed by own R&D, commercially introduced.
2006	• Punjab Tractors under performed the industry as volumes grew by 4% as against the industry growth rate of 18%. While it lost market share in both, the above 40 HP range and 31 - 40 HP range, the same more than doubled in up to 30 HP range.
2007	• Mahindra & Mahindra Ltd., the fourth largest tractor manufacturer in the world and the domestic leader for 23 consecutive years, acquired 43.3 percent stake in Punjab Tractors Ltd.in 2007.

5.5.2 Performance Indicators

Increased agri-focus of the Indian Government and the low penetration of tractors in the domestic market provide significant scope for business expansion, which PTL intends to leverage through its strong marketing initiatives like brand building, creating stronger franchisees, restructuring dealerships and introduction of new products. Additionally, the company has the advantage to synergize with Mahindra and Mahindra (M&M), Farm Equipment Sector (the market leader in the tractor industry) in the areas of sourcing, manufacturing, product development and distribution. The consolidated market share of the Farm Equipment Sector of M&M and PTL is now around 40% of the domestic market.

However, over the last four years, the prices of important inputs like steel, pig iron and rubber have been increasing continuously. The price of crude oil has also increased significantly in the 2007-08 year. Simultaneously, the export business has been adversely affected due to the significant appreciation of the Indian rupee against the U.S. dollar. As a result of all these factors, margins continued to be under pressure.

The snapshot of various financial performance indicators of the company and their trends has been discussed and presented in figure 5.7.

Net Sales: The net sales from operations was Rs. 5973 mn in 2003-04 which was increased by 43% to Rs. 8551 mn in 2004-05 due to high demand and low interest rates in the market. In 2005-06, it rose by 12% to Rs. 9595 mn. But after that the company has been hardly maintaining this sales level. The net sales dipped negligibly to Rs. 9589 mn in year 2006-07 and further restore to Rs. 9696 mn in year 2007-08.

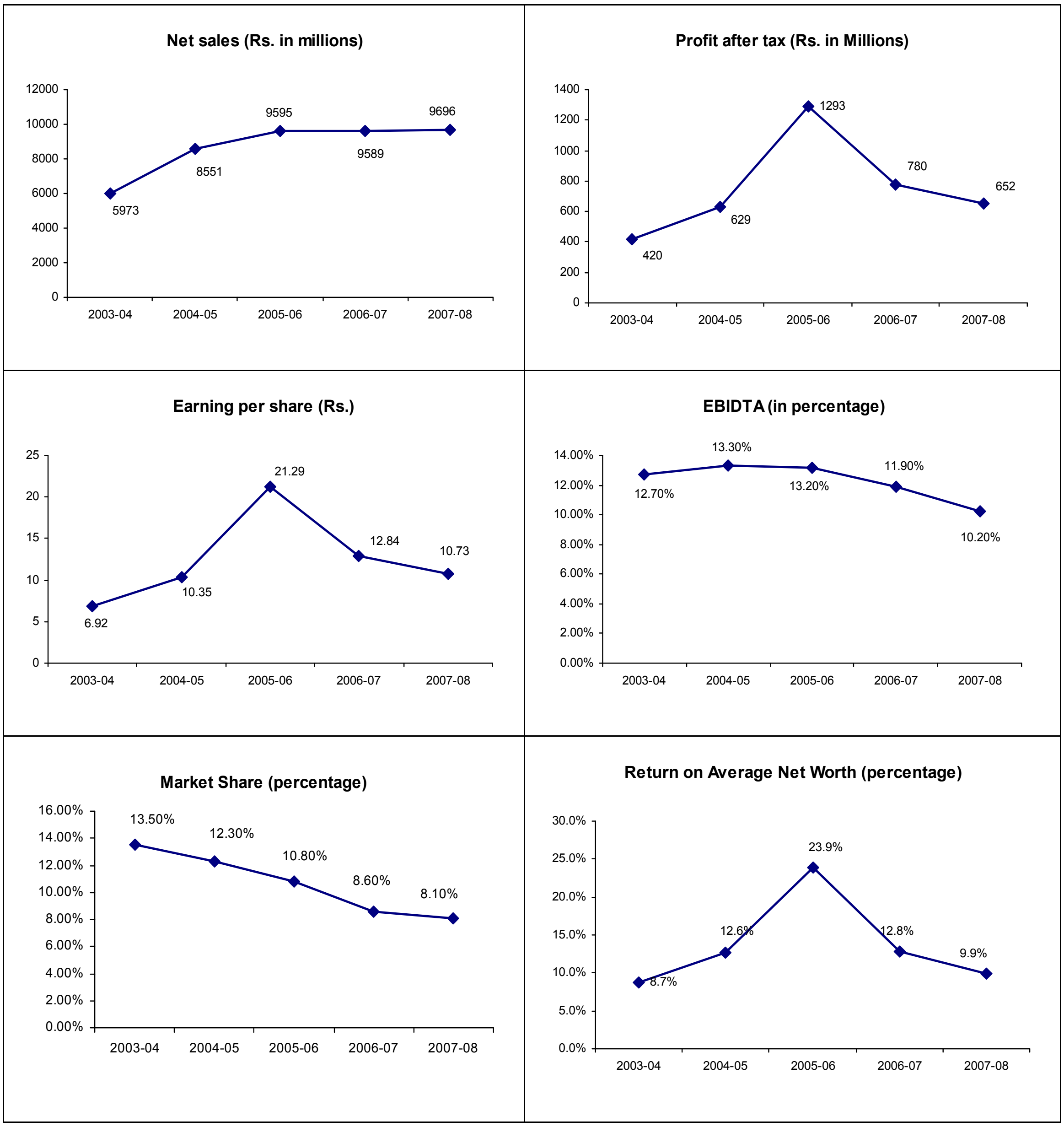


Figure 5.7 Performance indicators of PTL

Profit after Tax: The profit after tax (PAT) showed a large variation among the years of study. The PAT was Rs. 450 mn in year 2003-04 which significantly increased by 50% to Rs. 629 mn in year 2004-05 due to high sales record of the company for this year. The trend of shooting up of PAT continued for the next year i.e. 2005-06 when it jumped by 106% to Rs. 1293 mn. The year 2006-07 was not a year of new hopes for PTL, when its sales become stagnant and due to increasing costs of inputs, the PAT for the year 2006-07 slashed by 40% to Rs. 780 mn. But the year 2007-08 became even worse for the financial books of the company when it's PAT further slashed by 16% to Rs. 652 mn.

EBITDA: EBITDA margin was recorded to be 12.7% or the year 2003-04. It increased to 13.3% for the year 2004-05, then fell marginally to 13.2% in year 2005-06. Following the trend of falling EBITDA margin, it worked out to be 11.9% for the year 2006-07 and 10.2% for year 2007-08 because of stagnant sales and rising costs of inputs.

Earnings per Share: Earnings per share for 2004-05 was at Rs. 10.35, against Rs. 6.92 in 2003-04, a rise of 50%. Earnings per share for 2005-06 were at Rs. 21.29 showing an impressive growth of 106% over the previous year. However, the company sales got stagnant after that and due to increase in costs of input, earnings per share for 2006-07 were Rs. 12.84 and further fell to Rs. 10.73 for the year 2007-08.

Market Share: The market share of PTL is showing a continuous falling trend. In year 2003-04, the market share of PTL stood at 13.5%, which fell to 12.3% in year 2004-05. It further fell to 10.8% in 2005-06, 8.6% in 2006-07 and now stood at 8.1% in year 2007-08. In spite of increasing tractors demand at national level, this continuous falling trend in the market share of PTL may be accounted for the better products offered by the competitors.

Return on Average Net Worth: The Return on Average Net Worth was 8.7% in year 2003-04 which increased to 12.6% in year 2004-05. It further significantly increased to 23.9% in year 2005-06. But again due to stagnant sales and plunging profits, the return on average net worth reduced to 12.8% in year 2006-07 and further to 9.9% in year 2007-08.

5.5.3 Manufacturing Capacities and Capabilities

The company started its journey in 1970's with the launch of Swaraj tractor and capacity of 5000 units per annum. However the lack of ancillary units and local vendors for the supply of components have desisted the company plans to achieve higher profitability in the initial stages of its inception. The company continual its efforts in research and manufacturing facilities over the decades and timely Government support helped to achieve the capacity target of 24,000 units per annum in 1993. By that time, the company started feeling the pressure from its competitors, which have the excellence in technological and manufacturing facilities. To retain its position in the market, the company through its internal accruals has expanded its capacity by another 12000 units per annum in 1995 with the establishment of its second plant at chhapercheri. The company shifted its focus to effectively manage system aspects along with the advancements in technology in the late 90's. The effective use of sourcing practices, value analysis techniques, adoption of Juran philosophy and information technology helped the company to increase its capacity to 60,000 units per annum for its both plants by 2000, which further increased to 72,000 by the 2001. The company has achieved the target of selling 5 lacs units by 2002. But due the draught conditions in the parts of the country later on, stiff market competition in terms of product quality and cost has restricted the company's profit margins and position in the market during the next 5 years.

The company has launched a number of models in the different segments from time to time. The company has attained high-level of modification flexibility through its internal research and vendor support system. The products have been continually modified for their technological and operational aspects. The company has restricted the suppliers' involvement in the critical strategic decision-making process. Due to cost reduction exercises, value-engineering efforts, better buying practices and sourcing synergy with Mahindra & Mahindra Ltd. the company has managed to retain and regain its market share in the recent times.

5.5.4 Role of Technology

PTL is working towards localization, development and testing of products - both new and existing. This helps in indigenization of various vehicle aggregates at lower costs. In house R&D has helped the company to indigenously develop and implement automation so as to reduce cycle time. Capabilities strengthened in component and assembly evaluation, benchmarking and design optimization has further improved and upgrade existing models for value for money. The company has not imported any technology in the recent past. However, through local R & D efforts, the process and product modifications have been done. The ratio of expenditure on R&D as percentage of total turnover has been range bound in the recent years. Major technological and R&D activities in the previous years have been delineated below, which in course helps to achieve the higher level of manufacturing flexibility at all levels:

In 2007-08:

- Swaraj-855 tractor engine improved for fuel efficiency and introduced on regular basis.
- Swaraj-744 tractor engine improved for fuel efficiency and pilot lot introduced.
- New Tamil Nadu special variant of Swaraj-735 tractor model was commercially launched.
- Swaraj track type combine, designed & developed by in-house R&D was commercially launched.
- Swaraj 3 tonne battery forklift, designed & developed by in-house R&D was commercially launched.

- On-going product improvement projects for performance, reliability and value addition continued with vigor.

In 2006-07:

- Swaraj 724 FE Orchard Special tractor model commercially launched.
- Swaraj 978 FE (72 HP) tractor model commercially introduced in domestic market.
- New sheet metal with contemporary styling introduced on Swaraj 744 FE tractor model.
- New sheet metal introduced on Swaraj 735 FE tractor model.

In 2005-06:

- Engines meeting Bharat (Term) Stage III emission standard commercially introduced on all tractor models in April 2005, six months ahead of Government enforcement date.
- Sheet metal with contemporary styling developed and cleared for introduction.
- Suitable variants of existing tractor models were developed and introduced to meet region/application specific needs of discerning Swaraj customers.

5.5.5 Role of Sourcing Practices

The adoption of different sourcing practices has helped the company to manage the speed of capacity changeover in the manufacturing system, easy access to new technology, reduction in operating cost and risk of business to an extent. The company maintains a win-win relationship with its suppliers and strives to establish long-term relation. However, owing to organizational complicacies and confidentially dependence, the company has restricted the supplier(s) involvement in product design and development stage. Furthermore, the supplier involvement in modifying the products has a limited scope for the company. The flexibility competence of suppliers in managing demand fluctuations and supplier consistency has been among the company's frontline priorities for their selection. Cross-functional teams with the suppliers have helped the company to achieve flexibility and reduce cost through elimination of waste at their places.

The adoption of different sourcing practices has enhanced the process capabilities, speed of delivery and company image in the market. However, increased competition from the local and foreign suppliers, draught conditions over the various regions and untimely dealers' collections hold down its overall profit market share and position.

A close relationship with the suppliers' has significantly improved the company ability to achieve flexibility and execution competence. The suppliers' technological capabilities have moderately influenced the achievement of modification flexibility. The company has developed the cross functional teams with the key suppliers for making amendment in the processes and products and rolling out modified products.

5.5.6 Environmental and Social Aspects

The company has been committed towards excellence in occupational health and environment. This is also to ensure sustainable business growth. The company has a well established occupational and environmental policy, which inter alia ensures safety of public, employees, plant and equipment by ensuring compliance with all statutory rules and regulations on regular basis. The company also imparts training to its employees as per the predefined training calendar, carries out statutory safety audits of its facilities as per legal requirement, conducts regular medical check-up of its employees and promotes eco-friendly activities. The three plants of the Company at Mohali, Chappercheri and Majri have been certified with ISO 9000 and the process for ISO 14000 and 18000 certification for all these plants is in progress.

5.5.7 SWOT (Strength, Weakness, Opportunity, Threat) Analysis

On the basis of the study carried out in PTL, SWOT analysis has been done in which the strengths, weaknesses, opportunities and threats for this company has been identified. Table 5.22 shows the SWOT analysis at PTL.

Table 5.22 SWOT analysis at PTL

Strengths	*Weaknesses*
• Government support through Punjab State Industrial Development Corporation (PSIDC). • Capability to develop its own technology • In house R&D centre. • Manufacture of wide range of tractors for satisfying needs of all customers. • No imported components in the tractors • Capability to diversify in the allied areas like harvester combine, multicrop thresher and also LCVs. • Large chain of dealers and vendors. • High level of commitment from top management. • Large sales and service network. • Strong relationship with farmers. • A culture encouraging learning, experimentation and ownership feeling.	• Absence of support from any MNC in technological development. • Governed by government rules and regulations in routine affairs because of being a public sector unit. • Bureaucratic systems and procedures • Dependence of farmers on monsoon in a large part of India.

Opportunities	Threats
• Higher standard of living after green revolution • Rising demand of farming equipment in North India • Large agricultural land in India, second largest in the world • Increase of mechanized farming • Export avenues in the neighboring countries • Assembly of engines for farming purposes other than manufacturing tractors	• Shrinking demand of tractors due to draught and natural calamities • Fragmented land with farmers • Existing level of subsidies and impact of impending WTO regime. • Increasing prices of diesel in the international market • Entry of MNCs with advanced technology in Indian tractor industry • Government decision to disinvest its share to M & M. • Competition with Chinese cheap alternatives

5.5.8 Status of Manufacturing Flexibility

The company has managed to achieve the wide-ranging levels of manufacturing flexibility dimensions, despite the fact that its main focus is to attain quality leadership and access to the new customers/market creations. The company has an ability to achieve the varied production volumes, process improvements and manufacturing system expansions without sacrificing the quality levels. The company has a moderate capacity to introduce large number of product categories in the manufacturing system and the handling of many different delivery sequences. Likewise, the product configuration can be changed many times during the manufacturing process to accommodate customer preferences. The manufacturing system can put the new product design into production quickly, although the company feels it moderately important to introduce rapid design changes in the product.

The ability of the company in managing different manufacturing flexibility tasks ranging from high to low are, responsiveness to customer demands, improved processes and quality leadership, production of wide variety of product mix and the adaptation of organization structure to the volatile business environment and rapid delivery of innovativeness in design of the products.

Volume flexibility: The company has an ability to quickly respond to any increase or decrease aggregate output level for a given product mix, with minimal disruption to current operations and without any unacceptable effect on cost and other competitive criteria. The quality of the goods produced is not affected by the changes in volume. Over the period of time the company has redesigned the existing manufacturing system within the existing facilities and invested in the procurement of multipurpose machines to achieve the volume flexibility. The company has managed to maintain its position as a leader in the responsiveness, customer satisfaction and quality leadership for the tractor segment.

Efficient use of network of suppliers and vendors has helped the company to respond to uncertainties in demand. The ability of a supplier to absorb demand fluctuations lessens the need to carry safety stock, resulting in less inventory costs for responding to demand fluctuations. Accordingly, the company has used its supply chain network as a source of volume flexibility.

Modification Flexibility: The company has introduced ten tractor models with more than a hundred variants. Through its internal accruals and value chain with key suppliers' the company has managed to introduce the minor design and product modifications. Internal research and development facilities further increased the company's product modification capabilities. The company has invested in adoption of new technology in manufacturing and design including CNCs, Flexible Manufacturing Systems and CAD to enhance its capability to modify the products along with redesigning the existing manufacturing system with the available facilities. Supplier technological competence and consistency also moderately enhanced the modification capabilities of the company. A number of other factors including the capabilities of manpower employed, Government regulations, customer feedback and competitor competence have impacted the achievement of modification flexibility, though not considered in the present research.

The company has a moderate capacity for producing minor alterations in product design to meet customization, although the time required for introducing the modified product or product mix is considerable. The product modifications are accomplished with low transition penalties and small changes in performance outcomes. The company has also been able to improve existing models and offer many variants in each category.

Delivery Flexibility: The company has launched the customized products for new market creation periodically in domestic and international markets and handled rapid delivery of innovative products satisfactorily. Punjab Tractors has become a leader of class making a consistent profit over the years. Today, the company is even exporting premium products to the U.S. The Swaraj 855 tractor being exported to the U.S is greatly in demand due to its innovative features and ruggedness.

In order to meet market requirement, the PTL has normally been developing and adopting new technologies to keep its products at par with those of competitors in international and domestic markets. However, the company has not adopted any new technology from its collaborative partners and associates in the recent years. The company has launched the new products through its own internal research efforts and provides delivery differentiation profitably. It has a moderate capacity to produce product configuration that can be changed many times during the manufacturing process to accommodate customer preferences. The company prefers to abstain from having a long-term strategic relationship with its supplier base for achieving flexibility at any level.

Overall, the status of tactical and strategic level manufacturing flexibilities in the context of the study for PTL has been graphically revealed in figure 5.8.

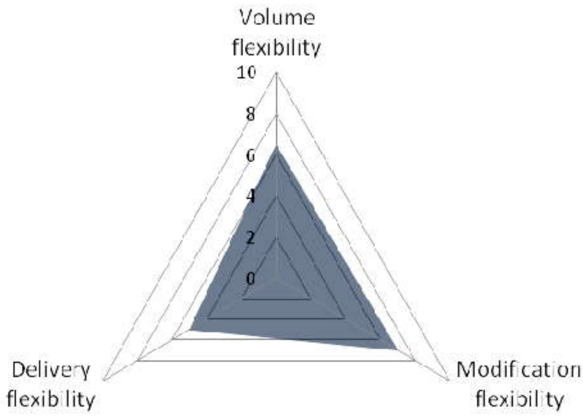


Figure 5.8 Status of manufacturing flexibility of PTL

5.5.9 Relative Performance of Technology and Sourcing Practices

The technology has played a moderate to significant role in achieving business excellence in terms of manufacturing flexibility, quality leadership and innovativeness in the highly competitive and turbulent market environment for the company. At the same time the involvement of the vendors at operational and tactical level helps in pacing the rate of growth for the company. The relative impact of adopting new technology vis-à-vis sourcing practices for achievement of different business objectives has been presented in the Table 5.23 below.

Table 5.23 Impact of adopting new technology and sourcing practices at PTL

		Impact of adopting new technology on performance objectives	**Impact of adopting sourcing practices on performance objectives**
1. PRODUCT QUALITY			
i.	Performance of products	+++	++++
ii.	Features of products	++++	+++
2. DELIVERY			
i.	Speed of delivery	+++	+++

ii.	Number of customized product offered	+++	+++
iii.	New product lead time	++	+++
3. FLEXIBILITY			
i.	Variety of modified products	++++	+++
ii.	Delivery of innovative products	+++	+++
iii.	Capacity to change product volume	+++	++++
3. COST			
i.	Product cost	+++	+++
ii.	Cost of future product innovations	+++	+++
5. EFFECT ON MARKET SHARE		+++	++++
6. NET PROFIT		+++	++++
7. OVERALL PERFORMANCE		**MODERATELY SATISFIED**	**MODERATELY SATISFIED**
(+) Significantly decreased, (++) moderately decreased, (+++) Remained the same, (++++) moderately increased, (+++++) significantly increased.			

The level of dependency on different sourcing practices for achieving the various manufacturing flexibilities is presented in Table 5.24. The role of technology and supplier involvement in managing capacity fluctuations has come out be important factor for achieving volume flexibility. Technology investment and supplier involvement through cross-functional teams are important for modification flexibility and investment in design technology and supplier competencies as technology supplier have significantly influenced the achievement of delivery flexibility.

Table 5.24 Dependency on different practices for achieving flexibility at PTL

Sourcing Practice →	**OUTSOURCING OF MANUFACTURING**	**STRATEGIC SOURCING** *(Outsourcing the in-house core competencies)*	**ADOPTION OF NEW TECHNOLOGY**
VOLUME FLEXIBILITY	+++	++	+++
MODIFICATION FLEXIBILITY	+++	++	++++
DELIVERY FLEXIBILITY	+++	++	+++ **(Main focus internal R& D, CAD)**
+ - *Not dependent, ++ - Least dependent, +++ -Moderately dependent, ++++ - Highly dependent, +++++ – Fully dependent*			

The company has achieved the different flexibility dimensions largely as a result of adoption of new technology and sourcing practices and at the same pace when compared to the competitors. Although, the pace of innovativeness in design and development of new products for whole of the farm equipment industry is comparatively slow. The company has effectively utilized their suppliers' capacities and capabilities to reduce the cost of the product. Furthermost, the company has developed its design capabilities over the period of time. Overall the company depending upon its key capabilities, time and type of actions and level of success in the market can be categorized as market challengers.

5.5.10 SAP Analysis at PTL

Based on the business strategy and initiatives taken by the PTL in the process of achieving the different manufacturing flexibilities, the situation-actor-process (SAP) analysis has been done. Table 5.25 shows the SAP analysis at PTL while LAP synthesis is described.

Table 5.25 SAP analysis at PTL

<table>
<tr><th>Situation</th><th>Process</th></tr>
<tr><td>
• PTL has developed its own technology, without any collaboration.
• Getting exemption of the excise duty.
• Localized vendors ensuring easy supply of components at reduced costs.
• Large number of models to satisfy all segments of customers.
• Diversification to harvesters and fork lifters.
• Recession in economy.
• Entry of MNCs in Indian market.
• Stable market share for the last three years although the tractors demand reduced in this period.
</td><td rowspan="3">
Technological aspects
• Making use of local manufacturing facilities, skill and raw material through a strong base of vendors.
• Reducing product development time by in-house research and development facilities.
• Saving costs through technology and efficient working.
• Introducing new features in the tractors as and when required.
• Further diversification to fork lifter, combined harvesters and others.
• Strengthening systems and quality assurance by Juran's approach.
• Reducing inventory level of the plant through JIT.

Sourcing issues
• Developing dealers' network and service network allover India.
• Developing local vendors for timely supply of parts and components.
• Cash dealing with dealers to avoid credit system.
• New vendor policy for ranking them based on their performance.
• Cost reduction exercises, value-engineering efforts, better buying practices and sourcing synergy with Mahindra & Mahindra Ltd.
• Establishing center for research and development, human resource development, training of management staff, supervisors and workers.
• Starting cost reduction by avoiding wastage, increasing productivity and other employees' oriented efforts.
</td></tr>
<tr><th>Actors</th></tr>
<tr><td>
• Management of Mahindra & Mahindra Ltd.
• Role of Punjab State Industrial Development Corporation (PSIDC).
• Tier- I and tier-II suppliers to the company for managing business competitive with special focus to flexibility dimension
• All the dealers and employees of the organization.
• All the customers through feedback and suggestions.
</td></tr>
</table>

5.5.11 Learning Issues

Based on the detailed study and analysis of the business strategy and initiatives taken at PTL, the following leaning issues have emerged.

State of business: Tractor industry's performance in India has been closely associated with the demographic conditions, with the time, quantum and distribution of monsoon and Government policies. The company has to restructure its business strategies and initiatives accordingly.

Cost Cutting: The competition between existing Indian manufacturer and new manufacture/MNCs, and demand fluctuations has resulted in reduced prices.

- For, survival, the organizations have been compelled to adopt cost cutting strategy in a big way so as to retain their profit margins. It is seen that there is a lot of scope for cost cutting through strategies like improving supply chain management, reducing inventory, better dealer management, increasing plant productivity and quality and reducing waste, reducing plant overheads and making the vendors competitive.
- The effective use of infrastructural technology may also help the company to achieve the desired targets.

Flexibility: Though the company has achieved the manufacturing flexibility considerably at tactical level, it needs to develop further its competencies at a strategic level.

- The company has to explore the role of strategic sourcing and new technology in achieving the strategic level flexibility.
- The role of human resources can also be studied further to examine their role in achieving flexibility at all levels.

Technology: The company has developed the technology through its internal accruals and in house research and development efforts.

- The company has ability to plan and manage technical changes effectively and efficiently and well aware of technology issues.
- Further, the company has a capacity to assess and select cost effective technology solutions. The company also develops a technology strategy, which includes a framework with priorities and an action plan.
- However, in the present competitive scenario the company has to strengthen its position in the technology. The role of information and communication

technology has to be looked upon by the company to reduce waste and cost at all aspects. The investment manufacturing technology for automation of production and assembly lines can also be done.

- The company must conducts extensive analyses based on the trends of the past years before going for new technology. The company should consider the alternate process that can be developed in house for making new technology cost effective.
- The acquisition of major share by Mahindra & Mahindra has given a boost to the company to perform and prove its metal as a leader in the tractor industry.

Sourcing: The Company has maintained a close relationship with its key supplier base; though rely on small but high quality suppliers.

- The company has an agreement to the fact that supplier integration in manufacturing system will lead to organizational complications and loss of control. This approach has shown the way to restricted participation of supplier base at tactical and strategic level, in course increasing the cost of product to some extent and substantial delay in launching the new products.
- The company needs to look into the sourcing aspects more widely and effectively to sustain and develop its market share and reduce the waste and cost.

Customer Focus: Close interaction with farming community has been very important. PTL, from very beginning, has been customer focused and has maintained close relation with farming community. PTL has focused on enlarging its dealer base, besides upgrading services facilities. These strategies have prevented the other manufacturers to grab a large share of the market.

Pace of change: The company has to effectively manage and suitably space the small and big changes in its product line and product portfolio so as to achieve the business excellence. The company is also building core capabilities in some critical area and exploiting these to the maximum extent.

5.5.12 Action Suggested

Various initiatives taken at PTL to achieve flexibility, quality, performance and business excellence depicts a successful fight of the company against growing competition in Indian context. Because of draught and other natural calamities, the purchasing power of the farmers (customers) was severely affected and reduction in the demand was inevitable. But by the use of technological and sourcing aspects at PTL, it has been able to sustain competition. The company however should review its policies and procedures, plan new changes, implement them, check the results and act again. Vendor development needs to be continued for cost effectiveness, inducing flexibility and quality. The dealer base of the company needs to be revamped and resurfaced properly. The tier-I and II suppliers' needs to be trained through cross functional teams and effective supply chain. The company has not adopted any major technology in the last five years, which can be a gray area, hence needs to be further explored for attaining growth and business excellence.

5.5.13 Performance Expected

Major factors of importance for achieving manufacturing flexibility at tactical and strategic level that need to be closely monitored in this case are adoption of manufacturing and infrastructure technology either through in house R&D effort or from technology suppliers and optimal use of various sourcing practices, including early involvement of supplier for developing new or modified component and strategic sourcing.

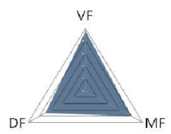
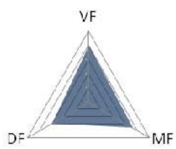
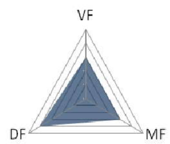
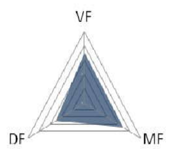
5.6 Comparison of different Organizations in Managing Manufacturing Flexibility

The case studies has been conducted in a phased manner starting from the evolution of the need for incorporating the manufacturing flexibility at the tactical level to the excellence at the strategic level by incorporating the new technology and sourcing practices as a competitive tool in different manufacturing enterprises. Critical analysis of case studies conducted in four manufacturing organizations has shown little variation in priority of objectives for managing manufacturing flexibilities. These have been comparatively analyzed and their results in Table 5.26 depicts the total industrial scenario about the perceived and achieved level of manufacturing flexibilities and assesses the relative impact of sourcing practices and new technology on different flexibilities for providing a basis for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities. Specific information related to commitment to business initiatives and performance, level of technology adoption and development, employment of supplier based sourcing practices and different aspects of manufacturing flexibilities have been presented in the digest and conclusive format.

Table 5.26 Comparison of business initiatives and strategies for achieving manufacturing flexibility by different manufacturing organizations

Organization		MSIL	SKSSL	Moser Baer	PTL
Product Mix		Passenger cars and MUVs	Automobile sub-assemblies	Storage media, Photovoltaic, Entertainment	Tractors / other farm and industrial machinery
1.	**COMMITMENT TO BUSINESS INITIATIVES AND PERFORMANCE**				
i.	**Type of organization**	OEM	Tier- I supplier	OEM/ Tier- I supplier	OEM
ii.	**Need for innovation and change**	Very High	High	Very High	Moderate
iii.	**Flexibility in manufacturing**	To a large extent	To a large extent	To a moderate extent	To a moderate extent
iv.	**Social and environmental commitment**	Include elements of partnership, sustainability, employee involvement, and scaling up of activities	Emphasis on team building, knowledge enrichment, energy saving initiatives	Commitment of seamless integration of marketplace, workplace, and environment	Sustainable business growth, , knowledge enhancement, eco-friendly activities
v.	**Customer focus and commitment**	Very High	High	Very High	High
vi.	**Quality leadership**	Very High, ISO9000	Very High, ISO 9000, Deming Award	Very High, ISO9002, OHSAS18001	High, ISO9000
vii.	**Manufacturing competence**	Very High, development of in house robots and automation, etc.	High, Innovative engineering and intelligent sourcing	Very High, mass customization, innovation in technology	High, indigenous technology, low cost productions, local vendors
viii.	**Role of cross-functional and cross- organizational teams**	Rapid delivery, smooth work flow, product modifications	Development of new design, low rejection rate, capacity management	Managing capacity demands and key components delivery	Purchasing of components, implementation of VA and improved products
ix.	**Effect of competitors' strategies**	Introduced MPS, VA, ERP, cross - organization teams with	Investment in design and manufacturing technology, vendor	Development of base technology and strategic sourcing	Higher supplier involvement, Strengthened the dealer network, in

		suppliers	consolidation		house R&D
x.	**Net sales, % change in last five years**	+ 112.1	+ 283.5	+ 18.51	+ 62.33
xi.	**Role of human factor in achieving manufacturing flexibility**	High	High	Very high	Moderate
2.	**LEVEL OF TECHNOLOGY ADOPTION AND DEVELOPMENT**				
i.	**Investment in infrastructural technology**	Very High, ERP, E-sourcing, WMS, E- nagare, VTS, Dealer management system	High, ERP Solutions, Seamless Sharing of Information, Process automation, JIT, SCADA system	Moderate, implementation of intermediate infrastructural technologies, AS/AR, AMHS	Low, JIT, MRPII, Quality systems,
ii.	**Investment in manufacturing technology**	Very High, automation and Robotics, CAM, FMS, AMHS	High, High end tubular technology, Virtual simulation, C-EPS	Very High, optical technology, Blu-ray format, crystalline silicon cell, film module plant	Moderate, local generation of technology through in house R & D efforts.
iii.	**Investment in design technology**	Very High, developed new technology in house	High, developed future technologies, CAE	Very High, developed in house base technologies	Moderate, local R& D efforts
iv.	**Main barriers to new technology adoption**	Cost of new technology adoption, likely obsolescence of technology	Cost of training & education adoption, cost of new technology, and skill deficiency for new technology.	Likely obsolescence of technology, cost of training & education	Company policy, cost of new technology adoption
v.	**In house research and development**	Very High	High	Very High	High
vi.	**Cross functional competence**	High	Moderate	Moderate	Moderate
3.	**ADOPTION OF SUPPLIER BASED SOURCING PRACTICES**				
i.	**Supplier involvement in manufacturing, i.e. non-strategic system**	High	High	Moderate	High
ii.	**Supplier involvement in**	High	Moderate	High	Low

	design and development, i.e. strategic sub system				
iii.	**Supplier consolidation and development**	Very High	High	Low	Moderate
iv.	**Knowledge transfer capabilities**	Very High	High	Moderate	Moderate
v.	**Supplier Relationships**	Long term strategic	Medium term tactical	Medium term strategic	Medium to low term, tactical
4.	**LEVEL OF DIFFERENT MANUFACTURING FLEXIBILITIES**				
i.	**Volume flexibility**	Very High	High	Moderate	Moderate
ii.	**Modification flexibility**	Very High	High	Moderate	High
iii.	**Delivery flexibility**	Very High	High	High	Moderate
iv.	**Comparison of manufacturing flexibility at tactical and strategic level**				

5.7 Concluding Remarks

Case studies have been conducted in four manufacturing organizations which are engaged in the process of adopting advanced manufacturing technologies and different sourcing practices. The role of new technology in comparison to sourcing practices at various levels of business operations has been analyzed for achieving the different tactical and strategic level manufacturing flexibilities. The trends in the performance indicators, business strategy and initiatives, commitment to social and environmental aspects for the individual company have been examined to understand and assess their role in achieving manufacturing flexibility. The practical difficulties and constraints faced by the organizations due to dynamic market environments with requirements of high manufacturing flexibility have also been examined. It has been observed that the various organizations are using different approaches for managing different manufacturing flexibilities, through the use of different sourcing practices and new technology adoption. Learning issues for each case study has been synthesized and comparative analysis has been done.

CHAPTER VI

DEVELOPMENT OF AN IMPLEMENTATION PLAN FOR MANAGING MANUFACTURING FLEXIBILITIES

6.1 Introduction

This chapter presents inferences drawn from empirical study carried out in manufacturing organizations of north India, case studies conducted in various manufacturing industries, synthesis of inferences, learning from various phases of the study, and use of learning issues in a structured manner within the boundaries of a qualitative model, to develop workable and effective management process for achieving manufacturing flexibility in Indian context. The inferences from each of the above phases have been compiled and listed. With a careful analysis, the overlapping and similar inferences have been scrutinized to develop a list of independent learning issues. These learning issues have then been taken as options for a qualitative modeling involving Option Field Methodology (OFM), Option Profile Methodology (OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST). Following this, an implementation plan has been developed for managing different manufacturing flexibility showing preferred strategies under various conditions of optimism, pessimism, and realism.

6.2 Synthesis of Learning Issues

Learnings from empirical study and four case studies has been synthesized and presented in the form of issues enumerated below.

Issues concerning Business Strategy and Initiatives

- Customer focus and commitment has been considered as the highly important business initiative by majority of the organizations.
- The role of technology and win-win situations with suppliers has been equally and significantly targeted by the organizations.
- Organizations have largely considered the importance of inducing flexibility in the manufacturing and design as an instrument for achieving competitiveness.

- Reduction in product cost and reliable quality at competitive price has emerged as the prime priorities for the organizations.
- Impact of market fluctuations and competitive excellence has emerged as prominent factors, for offering new or significantly improved products.
- Cross-functional teams wherever required have helped organizations in achieving business competitiveness.
- Recognizing the potential of technology and innovation, organizations have continuously harnessed the power of its knowledge capital.
- Seamlessly future proofing capital investments assures evolutionary capabilities of manufacturing infrastructure.
- The R&D initiatives have enabled the organizations to develop their own technology, designs and patents.
- With the association of research institutes, organizations aim to co-develop advanced futuristic product technologies to retain their position in the market.
- The organizations affirm their commitment of seamless integration of marketplace, workplace, and environment concerns with business operations.
- The organizations have attained the certifications from various international and national bodies and agencies for excellence in processes, products and operations, leading to achievement of business performance including quality, flexibility, productivity and competitiveness.

Issues concerning Technology Adoption

- The important factors for the implementation of AMT's include:
    - improvement in design and manufacturing capabilities
    - achievement of manufacturing flexibilities
    - Quality leadership in the market place.
- Speed of delivery and number of customized product offered has significantly increased due the adoption of new technology.

- The market share and net profit of the organizations have revealed a considerable improvement as a result of adopting new technology.
- Use of IT enabled systems helped the organizations to promote E-sourcing, enhance manufacturing flexibility, control waste and improve employee connect.
- Organizations have adopted the technology from their alliance partners to reduce lead-time to new product introductions.
- Organizations have largely invested in the Infrastructural technology so as to integrate their business operations within, with their suppliers and OEMs.
- To reduce the dependency on external suppliers, as a reason to adopt new technology, has emerged as of the lowest concern for the organizations.
- The high cost of new technology has been found as a main barrier for its adoption. The lack of information on new technology and customer non-responsiveness to new products has little effect in adopting the new technology.
- The cost of the existing and future product innovations have shown an upward trend, which can be resulted due to the high cost of technology acquisition in short term.

Issues concerning Sourcing Practices

- Supplier involvement has significantly and positively influenced the outcome of the organizations in terms of added flexibility, low cost and high profits.
- A participative and collaborative approach with the suppliers has emerged as a key factor for the growth of any manufacturing organization.
- Reduction in operating cost and speed of capacity changeover in manufacturing system has been considered as the leading factor to adopt the sourcing practices.
- Adaptability to customer’s need and requirement has been considered as important factor to adopt the sourcing practices.
- An organization’s ability to produce a quality product at a reasonable cost and in a timely manner is influenced by its suppliers’ capabilities.

- Supplier responsiveness to demand fluctuations and supplier modification capabilities have significantly influenced the supplier selection process.
- Suppliers' technological competences, improvement in product variety and low delivery time have been the important factors to adopt different sourcing practices.
- Organizations strive to establish a long-term strategically managed relationship with key suppliers, which in turn have a positive impact on the organization performance.
- Competitive scope of the suppliers has been a key area for the supplier selection.
- Supplier's integration in manufacturing system has low to moderate impact on an organization performance in terms of loss of control, confidentiality dependency and lead to organizational complicacies.
- Speed of delivery of innovative products has seen a considerable upside movement with the adoption of sourcing practices.
- Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage.
- Shift has been witnessed from capacity to system supplier.
- Organizations have witnessed the marginal decrease in product cost and substantial increase in net profit as a result of adopting and developing sourcing practices.
- Cross-functional and cross-organization efforts to increase flexibility and eliminate uncertainties have created the level of performance needed to create competitive advantage.
- The organizations have identified a group of suppliers for implementing an ERP solution enabling seamless sharing of information and promoting e business, flexibility and competitiveness as a measure for vendor consolidation.
- Longstanding strategic partnerships with key technology providers, allows the organizations to access new technologies.

Issues concerning Manufacturing Flexibility

- Majority of the organizations have a competence to considerably achieve the manufacturing flexibility at the tactical level.
- The organizations moderately rely on adoption and further development of manufacturing technology and infrastructure in house to achieve tactical and strategic level flexibilities.
- The responsiveness of the organizations to the customer demands and operating efficiently at different levels of output has emerged as the most important, amongst flexibility-oriented tasks.
- The considerable use of strategic sourcing has helped the organizations to achieve the strategic level flexibility, in course leads to the introduction of new products with minimal lead-time.
- Cross-functional teams have been found to be the key area of interest for achieving manufacturing flexibility.
- Adoption of ERP system has helped the organizations in achieving manufacturing flexibility and performs better in the global market.
- Some of the organizations (large scale) can handle the different delivery sequences quickly and efficiently to satisfy customer demands and creating new markets.

Issues concerning Volume Flexibility

- Significant investment in Infrastructural technology and the involvement of vendors in providing capacity support has helped the organizations in achieving volume flexibility.
- Most of the organizations have a capacity to handle volume changes and product configurations quickly and efficiently during the manufacturing process to accommodate customer preferences.
- Process improvement can be introduced in the manufacturing system without creating disturbances.

- Use of soft, administrative and intermediate technologies have resulted in strengthen the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly and profitably.
- Supplier involvement in modifying products has significantly shown a positive impact in managing the frequent volume fluctuations without sacrificing the quality of the different products.
- Volume flexibility has a significant correlation with the modification and delivery flexibility.

Issues concerning Modification Flexibility

- The augmentation of facilities with advanced manufacturing technology has helped the organizations to achieve the modification flexibility.
- The strategic use of organizational infrastructural resources has positively influenced the attainment of modification flexibility.
- The majority of organizations are capable of producing minor alterations in product design to meet customization.
- The cost of the modified or new product and transition penalties in course has been an area of concern for the organizations.
- Supplier assistance in minor product and process design changes and managing rapid changes in product variety have resulted in strengthening the organization capabilities to manage the achievement and development of modification flexibility.

Issues concerning Delivery Flexibility

- The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility.
- Cross-functional teams with the key suppliers has paid off in achieving fast delivery of innovative products and hence delivery flexibility.
- Supplier assistance in managing product and process changes for an organization played an imperative role as a prerequisite in developing delivery flexibility.

- The organizations maintain long term sourcing arrangement with key suppliers for achieving delivery flexibility.
- Flexibility of suppliers in effectively managing the market fluctuations for the deliverance of innovative products has been helpful for the organizations.
- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization.
- Delivery flexibility has a high and significant correlation with the achievement of volume and modification flexibility.
- A company with high delivery flexibility may be able to operate more economically, if it has already developed a high degree of volume and modification flexibility.

6.3 Methodology for Modeling – A Management Process

A qualitative model using Options Field Methodology (OFM), Options Profile Methodology (OPM), Analytic Hierarchy Process (AHP) and Fuzzy Set Theory (FST), has been developed and applied to the situation to meet the objectives, as shown in fig. 6.1, in a flexible system methodology framework (Sushil, 1993). A brief description of the model is given below.

OFM	OPM	AHP	FST
▪ Generating various options ▪ Putting options in categories ▪ Clustering the dimensions and sequencing	▪ Deciding various profiles or courses of action. ▪ Assigning options from options fields to profiles.	▪ Deciding the objectives or features of design. ▪ Paired comparison to decide weightage of features.	▪ Quantifying the contribution of each profile to each objective by making position matrices. ▪ Making weighted position matrices. ▪ Ranking the profiles under various schemes by dominance

Figure 6.1 Qualitative modeling approach

The modeling began with listing of options as a solution to flexible management of new technology for strategic success. The list was converted into a conceptual design. OFM/OPM (Warfield 1979, 1982, 1990) and was largely used as a basis for this purpose.

Finally, the alternative options profiles developed were been ranked using AHP (Saaty, 1980) and FST (Zadeh, 1965).

6.3.1 Options Field / Options Profile Methodology (OFM/OPM)

In order to adopt the method of idea writing (which Warfield termed idea management) to design, Warfield (1979) introduced a methodology for the conceptual design of systems which results into a portrayal on one page of the products of a conceptual design a foot. This portrayal shows not only what is accepted in the design but also what options are rejected. The Options Field Methodology and the Options Profile Methodology provide means for thorough development of design situation, descriptions and design target description.

They involve discovery and identification of dimensionality of the situation, and facilitate matching dimensionality of the target with dimensionality of the design situation. Various steps involved in these two methodologies are described below:

Options Field Methodology (OFM)

a) *Construction of a polystructure*: The completed options field is a polystructure. Its construction begins with the generation and classification of a set of options. This set may be generated using modified idea writing in response to a carefully formulated triggering question. This question defines the context and must, therefore, reflect substantial insight into the design situation. The question must be neither too broad nor too narrow. It must stimulate creative and productive responses that do not stray from the topic under consideration.

b) *Initial structuring (placing options in categories)*: Once a set is developed, the initial structuring begins. The initial structuring is for placing options into categories. A relationship that may be used for this initial structuring is “in the same category as”. Theory of dimensionality is used for placing the options into categories.

   The structural theory of dimensionality of situations and processes introduces options field and options profile as byproducts of design activity. Options field is a triply structured-quad, since it is a four levels structure, whose levels are named as Target, Cluster, Dimension and Options reading from the top to bottom (Fig. 6.2).

It is triply structured because its structure incorporates three distinct relationships (Warfield, 1990) described as membership in a dimension for classifying options into dimensions interdependence for classifying dimensions into interdependent cluster and time preference relationship” for relating dimensions to each other in clusters.

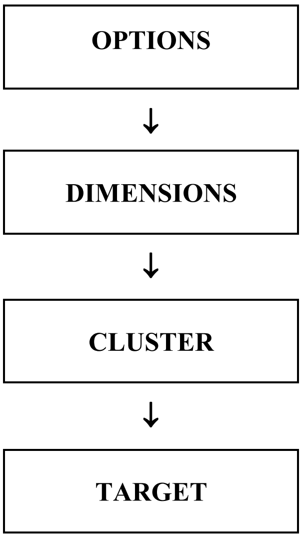


Figure 6.2 Four level structure quad.

c) *Identifying the design dimensions:* After the set of categories has been achieved, it is reasonable to believe that learning has occurred. At this point, it is appropriate to ask whether every category should be taken as a dimension of the design. The criteria for making this decision is to ask whether some option(s) in that category really must be specified in order to provide adequate definition of the alternative represented by choosing one or more options from each dimension, or whether any particular category is not essential to the definition of the target.

d) *Discovering Clusters of dependent dimensions*: Once the group has settled on the dimensions of the target, a second structuring occurs. Now the set of dimensions is structured. The relationship used is “independent of”. Two dimensions are defined to be independent if a choice of one or more options in one of the dimensions does not rule out any choices in the other dimension. If two dimensions are interdependent, the choice of options in one may be restricted by the choice of options in the other. Following this structuring, there is a defined set of clusters, each cluster consisting of a set of dimensions, and each dimension consisting of a set of similar options.

e) *Establishing a choice-making sequence for clusters:* Now the third structuring begins. This structuring takes the clusters as elements to be structured. The structuring relationship involves the sequence in which choices of options should be made. A suitable relationship is "should be considered first in making choices of options."

f) *Sequencing dimensions within clusters***:** A fourth structuring is carried out now. In this, structuring is carried out separately for each cluster and initial decision-making sequence among dimensions in each cluster is defined.

g) *Displaying the completed options field***:** It is then appropriate to organize the options field by placing dimensions in the order determined with name of each dimension heading a list of options therein and with the cluster clearly identified.

Options Profile Methodology (OPM)

Options Profile is the visual representation of an alternative consisting of a set of chosen options with at least one option coming from each dimension in the options field. Each option that has been selected is so designated by a line drawn from the bullet in front of the selected option down to the tie line. In applications, it is common to construct several options profiles for a given options field. Each options profile represents one design alternative. In choosing options, choices are made in the sequence determined in formulating the way options field is represented.

Having made the profiles, next task is to list various objectives of the design or targets. Following this, contribution of each profile to each objective is determined by paired comparison. Analytical Hierarchy process is employed for the purpose. A brief description of the AHP is given below.

6.3.2 Analytic Hierarchy Process (AHP)

Saaty (1980, 1982, 1986, 1990), Saaty and Vergas (1982), Saaty and Kearns (1985) describe and elaborate on the process.

Paired Comparison

Paired comparison is based on the idea that a complex issue can be effectively examined if it is hierarchically decomposed into its parts. The elements are compared with each other, thus providing an opportunity for a pair-wise comparison for evolving the structure into an nxn reciprocal judgment matrix. In the matrix, one begins with an element on the left and compares how much more important it is than an element on top. When compared with itself, the ratio is one. When compared with another element, if it is more important than that element, an integer value, as discussed below, is used. If, however, it is less important, then reciprocal of the previous integer value is used. In either case, reciprocal value is entered in the transpose position of the matrix. Thus, only n (n-1)/2 judgments are considered where n is the total number. The respondent is to concentrate on only two elements at a time. A scale of 1 to 9 is used for giving judgment value according to the following guidelines:

a_{ij} = 1 if i and j are equally important.

= 3 if i is weakly more important than j.

= 5 if i is strongly more important than j.

= 7 if i is very strongly more important than j.

= 9 if i is absolutely more important than j.

Value of 2, 4, 6 and 8 are used to compromise between two judgments.

The weightages of the features are obtained by calculating the Eigen Vector weights for the judgment matrix. An index of consistency is calculated to provide information on how serious is violations of numerical and transitive consistency. The results could be used to seek additional information and re-examine the data used in constructing the scale in order to improve consistency. The consistency index (CI) is = (Xmax – n) / (n-1) where n is the number of elements being compared and Xmax is the largest Eigen value of the judgment matrix. Dividing CI by the random consistency number for the same size matrix, consistency ratio CR can be obtained. The value of CR should be around 10% or less to be acceptable. In some cases, a maximum value of 20% may be tolerated. If CR is not within this range, participants should study the problem and revise their judgment. The average consistencies for different order random matrices are given below (Saaty and Kearns, 1985).

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.90	1.12	1.24	0.32	1.41	1.45	1.49

6.3.3 Fuzzy Set Theory (FST)

a) *Fuzzy set Theory (FST)* developed by Zadeh (1965) is based on recognition that certain sets have imprecise boundaries. Fuzzy sets and sub-sets are those ill specified and non-distinct collection of objects with unsharp boundaries in which transition from membership to non-membership is gradual rather than abrupt. A fuzzy set is characterized by a membership function, defined as a real number in the interval (0,1). For example, a membership measure (X) = 0.5 suggests that X is a member of set A to a degree 0.5 on a scale where 0 is no membership at all, and 1 is complete membership. Thus, a fuzzy set can be reduced to a crisp set by transforming memberships to extremes of the range zero or one. FST has been successfully applied to automata theory, system analysis, decision theory, man-machine systems, modeling of industrial processes etc. In this study, it has been used for the purpose of ranking of options profiles in an integrated form with analytical hierarchy.

b) *Ranking of alternatives using FST:* The fuzzy set methodology for multi-criteria decision making is used to analyze various options. The fuzzy set techniques are designed such that quantitative and non-quantitative factors, and the view points of the interest groups can be readily incorporated into the decision making process. Ranks of the options in a group process are achieved through a dominance matrix designed for the purpose.

In order to represent the views of each of the interest group, a position matrix is prepared from the responses of all the experts in the group by giving numerical values to the qualitative assessment. Average value of each element representing the group response is worked out by multiplying membership function value of each alternative as given by the respondents with assigned weight i.e. the eigen vector weight as determined by AHP. This way some of the bias in the matrix can be eliminated. The weighted matrices for each of the interest group are thus, prepared.

There are three ways to aggregate the weighted matrix viz. optimistic, average and pessimistic aggregation. The highest value among various group responses represents the optimistic value, the lowest value represents the pessimistic value and the average of all the values represents the mean value.

An n x n matrix 'D' called dominance matrix is prepared to display the dominance structure between all possible pairs of options. The element dij is the number of features for which membership value of option j dominates or is greater than option i. A dash is entered for the diagonal dij element. If the Kth column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the Kth row is summed, the number of times the Kth option is being dominated by all other options is determined.

Outcomes that are more favorable have higher column sums and lower row sums. In cases where an option is very close to another option on the basis of aggregate weighted position matrix, the dominance among the options exists only if the membership value of the second option is outside the specified limit. The options can be considered equivalent with respect to that feature. This range may be set for each problem (for example ± 5 percent of the membership value) but should not be too large, otherwise lot of information is likely to be lost. As in the case of weighted position matrices, three dominance matrices namely optimistic dominance matrix, pessimistic dominance matrix and mean dominance matrix are prepared.

The ranks of options are normally decided by examining ranks obtained from extent of dominance and also extent of being dominated by other options. Although any of the optimistic, pessimistic and average approaches can be used but there are shortcomings in each. The best course of action for a decision maker in such a situation may be to use a Hadley's criteria of cautious optimism (Hadley, 1967). The decision maker may choose different coefficients of optimism (16). If 'A' is the dominance weight of the option as determined from optimistic matrix and B that of the pessimistic dominance matrix, weight of the option according to Hadley criterion is determined by the relationship: $W = \alpha \times A + (1-\alpha) \times B$.

Since the process of choosing the coefficient of optimism (16)) in the Hadley criterion of 'Cautious Optimism' is a judgment based approach, ranks of the options from the dominance matrix is considered on the basis of dominance and ignoring the considerations of being dominated.

6.4 Qualitative Modeling using OFM, OPM, AHP, and FST

The learning issues as given in section 6.2 have been analyzed and restructured to convert them into following options of the OFM.

1. Design and development of new products
2. Customized products for new market creation
3. Access to new customers/ new market creation
4. Gain competitive excellence
5. Adoption, adaptation and further development of technology through local R&D efforts.
6. Delivery of innovativeness in design of products
7. Adoption of new technology for the new product design and development
8. Implementing quality systems procedures and practices
9. Cross functional teams with external suppliers for innovation in product design and development
10. Improvement in delivery of product variety
11. Introduction of process improvements in the manufacturing system
12. Rapid handling of increasing production volumes
13. Developing capacity to handle varied output volumes for the different products
14. Cost cutting and value analysis
15. Quality of the product not affected by changes in volume
16. Level of production volume be changed quickly
17. Transformation of new product design into production quickly
18. Capability of producing minor alterations in product design to meet customization
19. The time required to change to a modified product or product mix is short
20. The variety of modules/components enable many different products to be configured
21. Responsiveness to customers demand
22. To produce wide variety of product mix simultaneously

23. Development / fostering of next generation technology
24. Adoption of ERP and information technologies
25. Association with research institutes and technology partners.
26. Redesigning the existing manufacturing system within the available facilities
27. Investment in multipurpose machines
28. Technology acquisitions, adoption, adaptation, collaboration, tie-ups.
29. System design and implementation
30. Adoption of new technology in manufacturing systems
31. Use of specialized technology and capabilities of supplier(s)
32. Reduce operating cost and risk of business
33. Developing tier-1 and tier-2 suppliers to implement cost cutting technique
34. Economic and viable strategies
35. Adoption of infrastructure and information and communication technologies to improve flexibility
36. Investment in Soft technologies and administrative approaches
37. Acquiring world class technologies
38. High cost of new technology as a barrier for technology adoption
39. Involvement of supplier(s) in manufacturing
40. Involvement of supplier(s) in design and new product development process
41. Supplier responsiveness to demand fluctuations (volume changes, capacity etc.)
42. Supplier modification capabilities
43. Supplier integration in design
44. Design and innovative capabilities of supplier
45. Technological competence of suppliers
46. Vendor consolidation and development
47. Organization rely on small but high quality suppliers

48. Length of relationship
49. Participative and collaborative approach with the suppliers
50. Speed of capacity changeover and adaptability to customer needs
51. Early involvement of suppliers triggers innovations at the designing stage
52. Continuum shift from capacity supplier to system supplier
53. Longstanding strategic partnerships with key technology providers
54. Customer focus and commitment
55. Innovation and change
56. Win-win situations with suppliers
57. Integration of economic, environmental and social imperatives
58. Collaboration(s)/ Accreditation/ certification of the organization
59. Market share and net profit of the organizations
60. Flexibility in manufacturing
61. Quality planning and improvement
62. Market leadership through pro activeness
63. Use of flexible procedure and practices
64. Develop teams to make changes in system and continuously improve it
65. Reduction in production costs
66. Reduce the impact of market fluctuations
67. Economic viability study for adopting new technology
68. Average sales growth
69. Seamlessly future proofing capital investments
70. Use of value analysis/value engineering and system approaches
71. Improved processes and quality
72. To adapt itself or its organizational structure

Innovation, design and development	Market responsiveness	Vendor consolidation and development	Business strategy and performance	Keeping pace with technology
Design and development of new products Customized products for new market creation Access to new customers/ new market creation To gain competitive excellence Adoption, adaptation and further development of technology through local R&D efforts` Delivery of innovativeness in design of products Adoption of new technology for the new product design and development Cross functional teams with external suppliers for innovation in product design	Introduction of process improvements in the manufacturing system Rapid handling of increasing production volumes Developing capacity to handle varied output volumes for the different products Large product mix Quality of the product not affected by changes in volume Level of production volume be changed quickly Transformation of new product design into production quickly Capability of producing minor alterations in product design to meet customization The time required to change to a	Involvement of supplier(s) in manufacturing Involvement of supplier(s) in design and new product development process Supplier responsiveness to demand fluctuations *(volume changes, capacity etc.)* Supplier modification capabilities Supplier integration in design Design and innovative capabilities of supplier Technological competence of suppliers Vendor consolidation and development Organization rely on small but high quality suppliers Length of relationship Participative and collaborative approach with the suppliers Speed of capacity changeover in manufacturing system	Customer focus and commitment Innovation and change Win-win situations with suppliers Integration of economic, environmental and social imperatives Collaboration(s)/ Accreditation/ certification of the organization Market share and net profit of the organizations Flexibility in manufacturing Quality planning and improvement Market leadership through proactive ness Use of flexible procedure and practices Cost cutting and value analysis Develop teams to make changes in system and continuously improve	Development / fostering of next generation technology Adoption of ERP and infrastructural technologies Association with research institutes and technology partners. Redesigning the existing manufacturing system within the available facilities Investment in multipurpose machines System design and implementation Adoption of new technology in manufacturing systems Use of specialized technology and capabilities of supplier(s) Technology acquisitions, adoption,

Tie-line

Innovation, design and development	Market responsiveness	Vendor consolidation and development	Business strategy and performance	Keeping pace with technology
and development • Improvement in delivery of product variety • Role of strategic sourcing with key suppliers in innovation and design • Implementing quality systems procedures and practices	modified product or product mix is short • The variety of modules/components used, enable many different products to be configured • Responsiveness to customer's demand • To produce wide variety of product mix simultaneously	and adaptability to customer needs • Early involvement of suppliers triggers innovations at the designing stage • Continuum shift from capacity supplier to system supplier • Longstanding strategic partnerships with key technology providers • Developing tier-1 and tier-2 suppliers to implement cost cutting techniques	it • Reduction in production costs • Reduce the impact of market fluctuations • Economic viability study for adopting new technology • Average sales growth • Seamlessly future proofing capital investments • Use of value analysis/value engineering and system approaches • Improved processes and quality • To adapt itself or its organizational structure • Reduce operating cost and risk of business • Keeping track of competitors policies and practices	adaptation, collaboration, tie-ups, etc • Adoption of infrastructure and information and communication technologies to improve flexibility • Investment in Soft technologies and administrative approaches • High cost of new technology as a barrier for technology adoption • Develop in-house research and development capabilities

Outsourcing based approach

Strategic Sourcing based approach

Design Technology based approach

Manufacturing Technology based approach

Infrastructural Technology based approach

Figure 6.3 Options Profile methodology

6.4.1 Putting the Options into Categories

These options were then put into various categories and the categories were named too. The categories are:

a) Customized products for new market creation

b) Delivery of innovativeness in design of products

c) Development of technology in house and sourcing practices

d) Process and product improvements

e) Reduction of lead time to product development

f) Flexibility in manufacturing

g) Development / fostering of next generation technology

h) Technology acquisitions, adoption, adaptation, collaboration, tie-ups, etc

i) System design and implementation

j) Investment in soft and hard technologies

k) Develop in-house research and development capabilities

l) Customer focus and commitment

m) Market leadership through pro activeness

n) Techno-socio-environmental aspect

o) Economic and viable strategies

p) Quality systems standards

q) Supplier responsiveness and modification capabilities

r) Design and innovative capabilities of supplier

s) Participative and collaborative approach with the suppliers

6.4.2 Dimensions of the Design

The above categories were scrutinized to include them or exclude any of them for the design. All of these have been included and considered as the dimensions of the design.

6.4.3 Clustering

The dimensions were put into broader categories called clusters. The principles have already been explained. These are shown in the next section.

6.4.4 Sequencing of Clusters and Dimensions within Clusters

Following the clustering of the dimensions, the clusters were put into sequence as per the importance of an area. The sequencing of dimensions within clusters was then carried out. The resultant clusters with sequenced dimensions are given below:

i. ***Innovation, design and development***

   a. Customized products for new market creation
   b. Delivery of innovativeness in design of products
   c. Development of technology in house and sourcing practices

ii. ***Market responsiveness***

   a. Process and product improvements
   b. Flexibility in manufacturing
   c. Reduction of lead time to product development

iii. ***Vendor consolidation and development***

   a. Supplier responsiveness and modification capabilities
   b. Design and innovative capabilities of supplier
   c. Participative and collaborative approach with the suppliers

iv. ***Business strategy and performance***

   a. Customer focus and commitment
   b. Market leadership through pro activeness
   c. Techno-socio-environmental aspect
   d. Economic and viable strategies
   e. Quality systems standards

v. ***Keeping pace with technology***

   a. Development / fostering of next generation technology
   b. Technology acquisitions, adoption, adaptation, collaboration, tie-ups, etc
   c. System design and implementation

d. Investment in Soft and hard technologies
e. Develop in-house research and development capabilities

6.4.5 Options Profile Methodology

Various profiles or courses of action planned to achieve different dimensions of manufacturing flexibility at tactical and strategic level, for the purpose of this study are delineated as follows:

I. ***Outsourcing based approach (OS),*** i.e. achieving manufacturing flexibility primarily by outsourcing of sub strategic non-core activities in manufacturing and these may include:

- Supplier responsiveness to schedule volume changes and process design changes
- Supplier assistance in process improvement and speed of capacity changeover in manufacturing system
- Supplier involvement in managing rapid change in product variety

II. ***Strategic Sourcing based approach (SS),*** i.e. achieving manufacturing flexibility primarily by involving supplier in manufacturing, design and development aspects. In strategic sourcing, the competencies provided by the supplier network contain a high degree of knowledge and are those most complementary to in-house core competencies.

- Strategic sourcing targets the acquisition of supplier capabilities in alignment with purchasing, manufacturing, and corporate needs, with considerable lower risk exposure and greater responsiveness.

Furthermore, activities commonly associated with strategic sourcing include partnerships, cross-functional activities, joint planning meetings, and shared information systems.

III. ***Design Technology based approach (T_D),*** i.e. achieving manufacturing flexibility primarily by investment in manufacturing design technology and these may include:

- Computer aided engineering (CAE)/ Computer aided testing
- Computer aided design (CAD)

IV. ***Manufacturing Technology based approach(T_M),*** i.e. achieving manufacturing flexibility primarily by investment in manufacturing technology and these may include:

- Flexible manufacturing system (FMS)
- Computer aided manufacturing (CAM)
- Computerized numerical control machines (CNC)
- Robotics and Group technology

V. ***Infrastructural Technology based approach (T_I),*** i.e. achieving manufacturing flexibility primarily by investment in infrastructural technology and these may include:

- Intermediate technologies (AMHS, AS/RS)
- Soft technologies to schedule production (MRP, MRPII, KANBAN/ JIT)
- Administrative technologies (ERP, ABC, OA)

After deciding upon various profiles, the next task performed has been to find out the options from each cluster contributing to each profile. For this purpose, completed option fields have been displayed. A tie line has been drawn on the bottom. Each option contributing to a profile has been joined to the tie line through its bullet. This has been shown in Figure 6.3.

6.4.6 Analytic Hierarchy Process Modeling

Manufacturing flexibility at tactical and strategic level in the scope of this research have already been discussed and analyzed in chapter IV of the study. These include achievement of:

i) Volume flexibility

ii) Modification flexibility

iii) Delivery flexibility

Next, paired comparison method of analytical hierarchy process has been applied to find out the weightages of each objective. Three respondents compared each objective with each other, independently. These were: technology manager of Maruti Suzuki India limited, Gurgaon, R&D manager Punjab Tractors Limited and the researcher himself. The respondents compared the objectives on a qualitative scale of the difference between the importances of two criteria. They, however, wrote the response in quantitative terms by converting the qualitative response using the following scale.

Equally important	**Weakly more important**	**Strongly more important**	**Very strongly more important**	**Absolutely more important**
1	3	5	7	9

Matrices of these values as filled by the respondents are given in Appendix - G. These matrices also show the calculation of Eigen vector and the weights of the objectives. The weightings given by the respondents were quite consistent and the consistency ratio was found to be well within the limit of 10%.

The matrix containing weights of all the objectives as decided by various respondents is given in Table 6.1.

Table 6.1 Weights of various manufacturing flexibilities

Respondent ⇨ Objective ⇩	**Researcher**	**Sourcing Manager**	**Technology Manager**
Volume Flexibility	0.081	0.221	0.105
Modification Flexibility	0.188	0.319	0.258
Delivery Flexibility	0.731	0.460	0.637

The role of delivery flexibility has been found to be the largely important, followed by modification and volume flexibility. This could be attributed to the fact that the organizations these days are more focused towards the deliverance of new or customized products quickly and flexibly for achieving competitive excellence in the dynamic business environment. Fast obsolesces of the existing technology and competitor strategies have also influenced the organizations to shift their focus towards strategic level flexibilities.

The relative weight scored by volume flexibility is less than other two types of flexibilities i.e. modifying flexibility and delivery flexibility. The reason can be recognized to the fact that these days the organizations easily restructure their existing processes quickly to the varying customer demands. Additionally, the role of supplier involvement at tactical level can be managed with ease.

6.4.7 Fuzzy Set Theory

After determining the weights of the objectives, the next step has been to make position matrices. In these matrices, the qualitative value of contribution of each profile or course of action to each objective has to be decided. Again, the three respondents have done this exercise. The position matrices along with the weights determined earlier are given in Appendix - H. From the position matrices, weighted position matrices have been determined. This has also been done individually for the matrix from each respondent. The weight of the objective as determined earlier has been multiplied by value of each position of the position matrix and weighted values have been obtained. Appendix - I shows the weighted position matrices.

From these weighted position matrices, optimistic, average and pessimistic weighted position matrices have been made using Fuzzy Set Theory. For optimistic matrix, the highest value of each position has been selected, for pessimistic the lowest values and for average matrix, the average values have been selected. Tables 6.2 to 6.4 show these values.

Table 6.2 Optimistic weighted position matrix

Profile ⇨ **Objectives ⇩**	**Outsourcing based approach**	**Strategic Sourcing based approach**	**Design Technology based approach**	**Manufacturing Technology based approach**	**Infrastructural Technology based approach**
Volume Flexibility	0.1548	0.0663	0.0663	0.1548	0.1548
Modification Flexibility	0.1808	0.1808	0.1808	0.2232	0.1595
Delivery Flexibility	0.2192	0.6576	0.5115	0.2192	0.3220

Table 6.3 Pessimistic weighted position matrix

Profile ⇨ **Objectives ⇩**	**Outsourcing based approach**	**Strategic Sourcing based approach**	**Design Technology based approach**	**Manufacturing Technology based approach**	**Infrastructural Technology based approach**
Volume Flexibility	0.0729	0.0243	0.0243	0.0524	0.0567
Modification Flexibility	0.0942	0.1319	0.0942	0.1291	0.1291
Delivery Flexibility	0.1380	0.3220	0.3185	0.1380	0.1911

Table 6.4 Average weighted position matrix

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.1073	0.0407	0.0407	0.0933	0.1019
Modification Flexibility	0.1448	0.1574	0.1448	0.1614	0.1402
Delivery Flexibility	0.1828	0.5176	0.3840	0.1828	0.2441

Based on above optimistic, pessimistic and average weighted position matrices, other matrices have been computed at various degrees of optimism (80%, 60%, 40% and 20%) and tabulated in Appendix – J.

India, at the moment, is passing through a transition phase. After the IT boom, a manufacturing revolution has been well underway in the Indian economy, spurred on by the increasing presence of multinationals, scaling up of operations by the domestic companies and expanding domestic market. The sector has been averaging 9 per cent in the last four years (2004-08), with a record 12.3 per cent in 2006-07. India's manufacturing base, which is the fourth-largest among emerging economies, is among the fastest growing and has seen more investments as a proportion of gross domestic product than any country except China. However, global competition has already reached the unprecedented levels and India has to fully develop its manufacturing industry in line with global leaders in coming years. In such circumstances, a pessimistic approach in managing manufacturing flexibility is not expected to succeed. On the other hand, a pure optimistic approach may also not yield the desired results because of the lack in Infrastructural and technological competence, deficiency in structural factors and the level of buyer-supplier orientation existing in the country. Additionally, current scenario in the global market in terms of economic imbalances and manufacturing recession also put a cap for the implementation of optimistic approach to certain extent. In such a scenario, a cautious optimism approach with quite a high degree of optimism may be employed.

The outcome of weighted position matrices for optimism, pessimistic, average and different cautious approaches have been compiled in the Table 6.5, which depicts the comparative association between different flexibilities and various profiles.

Table 6.5 Preferred strategies under cautious optimism for achieving various flexibilities

Objective ⇩	Optimistic	80% Optimistic	60% Optimistic	40% Optimistic	20% Optimistic	Pessimistic	Average
Volume Flexibility	T_I-OS-T_M	OS- T_I-T_M	OS- T_I-T_M	OS- T_I-T_M	OS- T_I-T_M	OS- T_I-T_M	OS- T_I-T_M
Modification Flexibility	T_M- T_D- SS	T_M - SS-T_D	T_M - SS- T_I	T_M - SS- T_I	T_M - SS- T_I	SS- T_M - T_I	T_M - SS- T_I
Delivery Flexibility	SS- T_D - T_I	SS- T_D - T_I	SS- T_D - T_I	SS- T_D - T_I	SS- T_D - T_I	SS- T_D - T_I	SS- T_D - T_I

(OS- Outsourcing based approach; SS- Strategic sourcing based approach; T_D - Design technology based approach; T_M - Manufacturing technology based approach; T_I - Infrastructural technology based approach)

The following observations have been outlined from the Hadley's matrix of cautious optimism as detailed in Table 6.5.

- Outsourcing of sub strategic activities in manufacturing and investment in infrastructural and manufacturing technology has significantly influenced the achievement of volume flexibility in Indian large and medium scale manufacturing organizations in most of the optimism conditions. Involvement of suppliers in managing volume changes requests has emerged as a foremost aspect followed by investment in infrastructural and manufacturing technology.

- Investment in manufacturing and design technology has primarily influenced the achievement of modification flexibility in most of the matrices conditions closely followed by involvement of supplier in managing minor product and process modifications requests. However, in pessimistic conditions, the role of supplier has become strategic in nature and the organizations tend to use the knowledge and technological competencies of supplier base. Further, the outsourcing of manufacturing activities and investment in manufacturing technology has moderately influenced the achievement of modification flexibility in pessimistic conditions.

- Rapid delivery of innovative products, customized products for creation of new market and delivery differentiations has been the key aspects of the delivery flexibility. The strategic role of supplier base has emerged to be the primary and most important aspect in achieving delivery flexibility. The organizations tend to maintain a long-term relationship and achieve delivery flexibility by involving supplier in manufacturing and design and development aspects. Further, the investment in design technology and infrastructural technology has influenced the achievement of delivery flexibility.

Following this, dominance matrices have been prepared. In these matrices, the dominance of each course of action over the others has been tabulated. The cell value denotes that a course of action dominates other courses of action in how many criteria and it is dominated by another course of action in how many criteria. In the matrix, profile written on the top, dominates the profile written on the left. Thus, row sum depicts the number by which a criterion is dominated and the column sum depicts the number by which the profile dominates all other profiles.

The matrices are presented in Table 6.6 to Table 6.9.

Table 6.6 Dominance matrix - optimistic

Profile	**OS**	**SS**	**T_D**	**T_M**	**T_I**
OS	--	1	1	1	1
SS	1	--	0	2	1
T_D	1	1	--	2	1
T_M	0	1	1	--	1
T_I	1	2	2	1	--
Column Sum	3	5	4	6	4
Rank	**V**	**II**	**III**	**I**	**III**

In the optimism dominance matrix, ‘manufacturing technology based approach’ has emerged as the preferred strategy for achieving manufacturing flexibility at strategic and tactical level. Further, ‘design technology based approach’, and ‘Infrastructural technology based approach’ have occupied the second position, followed by outsourcing and strategic sourcing based approach.

Table 6.7 Dominance matrix - pessimistic

Profile	OS	SS	T_D	T_M	T_I
OS	--	2	1	1	2
SS	1	--	0	1	1
T_D	1	2	--	2	2
T_M	1	2	1	--	2
T_I	1	2	1	0	--
Column Sum	4	8	3	4	7
Rank	**II**	**I**	**V**	**III**	**II**

The result of pessimistic matrix depicts the significant importance of strategic sourcing and infrastructural technology for achieving manufacturing flexibility at strategic and tactical level.

Table 6.8 Dominance matrix - average

Profile	OS	SS	T_D	T_M	T_I
OS	--	2	1	1	1
SS	1	--	0	2	1
T_D	1	2	--	2	1
T_M	1	1	1	--	2
T_I	2	2	2	1	--
Column Sum	5	7	4	6	5
Rank	**III**	**I**	**V**	**II**	**III**

In average dominance matrix, ‘manufacturing technology based approach’, ‘design technology based approach’, and ‘infrastructural technology based approach’ have emerged as the preferred strategies as all the three have been ranked as number one, followed by ‘strategic sourcing based approach’ that seems to be a emerging approach in the large scale Indian manufacturing organizations.

The similar dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled in Appendix – K. The results of Hadley’s dominance matrix of cautious optimism are also in line with the optimistic and the average matrix.

The results of all the dominance matrices have been summarized in Table 6.9.

Table 6.9 Hadley's matrix of cautious optimism

Rank ⇨ Profile ⇩	Optimistic	80% Optimistic	60% Optimistic	40% Optimistic	20% Optimistic	Pessimistic	Average
Outsourcing based approach, OS	V	III	IV	IV	IV	II	III
Strategic Sourcing based approach, SS	II	I	I	I	I	I	I
Design Technology based approach, T_D	III	V	V	V	V	V	V
Manufacturing Technology based approach, T_M	I	II	III	III	III	III	II
Infrastructural Technology based approach, T_I	III	III	I	I	I	II	III

The results indicate that strategic sourcing based approach has affirmed as the most preferred strategy whereas design technology based approach has occupied the last (fourth) position for managing the manufacturing flexibility under all degrees of optimism. Infrastructural technology based approach and manufacturing technology based approach have occupied almost equal rank under various degrees of optimism. The dominance matrix for a high degree of optimism (80%) seems to be the most realistic strategy. In these matrices, strategic sourcing based approach has emerged as the most preferred strategy; manufacturing technology based approach has got the second rank, whereas infrastructural based approach, outsourcing based and design technology based approaches combined have come into sight as the preferred strategies ranked as number three and four respectively.

6.5 Discussion and Development of the Generic Plan

The manufacturing sector in India has been witnessing a paradigmatic shift in the recent years from mass production to mass customization resulting from 'smarter' production technologies and sourcing initiatives that are tailored to the needs of specific designs and customers. The manufacturing industry has been passing through a transformation phase where each organization is focusing its business strategy and processes towards the achievement of competitive excellence and providing customers with the optimized products quickly and flexibly. Underneath the current scenario, the impact of advanced manufacturing technology and sourcing practices have become imperative for achieving flexibility competence; cost competitiveness, quality conformance and delivery differentiations for the organizations. Further, firms are likely to attain flexibility in manufacturing, deliver new or modified product and process design quickly and cost effectively as a result of their technological competence and planned use of supplier based sourcing practices. Though, the deployment of sourcing practices have attained marginal lead in delivery, flexibility and net profit aspect, new technology go ahead moderately in quality and market share. A system shift has been witnessed towards the achievement of strategic success with the rapid delivery of innovative and customized products to the customers. Results of qualitative modeling, which are in fact an outcome of opinion of the experts, taken in structured way depict the relative impact of technology and sourcing based approaches in achieving the volume, modification and delivery.

6.5.1 Preferred Approaches for achieving Volume flexibility

The strategic purpose of volume flexibility is to help cope with aggregate demand uncertainty. Volume flexibility permits the firm to adjust production upwards and downwards within wide limits. The outcome of the results in the domain of qualitative modeling portrays the relative importance of new technology and sourcing practices intended for achieving volume flexibility. The following approaches have found to be significantly important in order of their occurrence for the achievement of volume flexibility.

i. Outsourcing based approach
ii. Infrastructural technology based approach
iii. Manufacturing technology based approach

It has been inferred that for achieving volume flexibility, the foremost attention has to be given to outsourcing of sub strategic manufacturing activities. Systematic employment of sourcing practices has facilitated the firms to exploit the ability of their suppliers for quickly responding to the uncertainties in the dynamic market. The greater the deployment and use of sourcing practices (such as outsourcing, supply and distribution networks, and strategic alliances) are present within the organization; the greater the source of volume flexibility is available to the organization. Strategic sourcing also has a limited positive influence on the achievement of volume flexibility.

This has been followed by technology investment in manufacturing infrastructure including the explicit use of soft, administrative and intermediate technologies, in result strengthening the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly and profitably. Information and communication technology has played a significant role in achieving volume flexibility by the seamlessly integrating the various processes and information within and outside the organization. Integrated production control systems, such as manufacturing resource planning (MRP II) and enterprise resource planning systems (ERP), reduce inventories and raw materials, work-in progress and finished goods. Additionally, the organizations have redesigned their existing system and structure within the available facilities, for effectively managing the volume capacity and variability. Furthermore, the investments in AMHS, AS/RS and activity based costing (ABC) systems have moderately assisted the organizations to handle volume fluctuations in the dynamic market place.

Subsequently, the investment in manufacturing technology has assisted the organizations to achieve volume flexibility. Organizations have invested in upgrading their manufacturing capabilities by installing FMS, CNCs and Robots at their workplace for effectively managing the related capacity and demand issues. Role of manufacturing technology has always been imperative for the organizations to build their capacity and ability to handle demand fluctuations.

The systematic plan for explicating the role of technology and sourcing practices for achieving volume flexibility has been developed and presented in figure 6.4. It has been illustrated that the impact of outsourcing of manufacturing has a significant impact on the achievement of volume flexibility and further facilitated by the introduction of investment in infrastructural technology. Next, the manufacturing technology in supplement to outsourcing and infrastructure technology has largely impacted the attainment of volume flexibility. As the focus of an organization shift towards the accomplishment of core competencies (including lean and agile manufacturing, rapid product and process innovations and mass customization) as a result to the addition of manufacturing facilities in design and development stage and strategic sourcing aspect, the focus of the manufacturing firms have limited and constrained the scope of volume flexibility to some extent.

The framework depicts the results in the optimized environment where a manufacturing organization uses a blend of technology and sourcing as a part of their business strategy for achieving flexibility competence. It is further understood that for implementing the design technology in a manufacturing system, an organization must have attained the desired level of competence in infrastructural and manufacturing technology vis-à-vis outsourcing prior to the strategy sourcing.

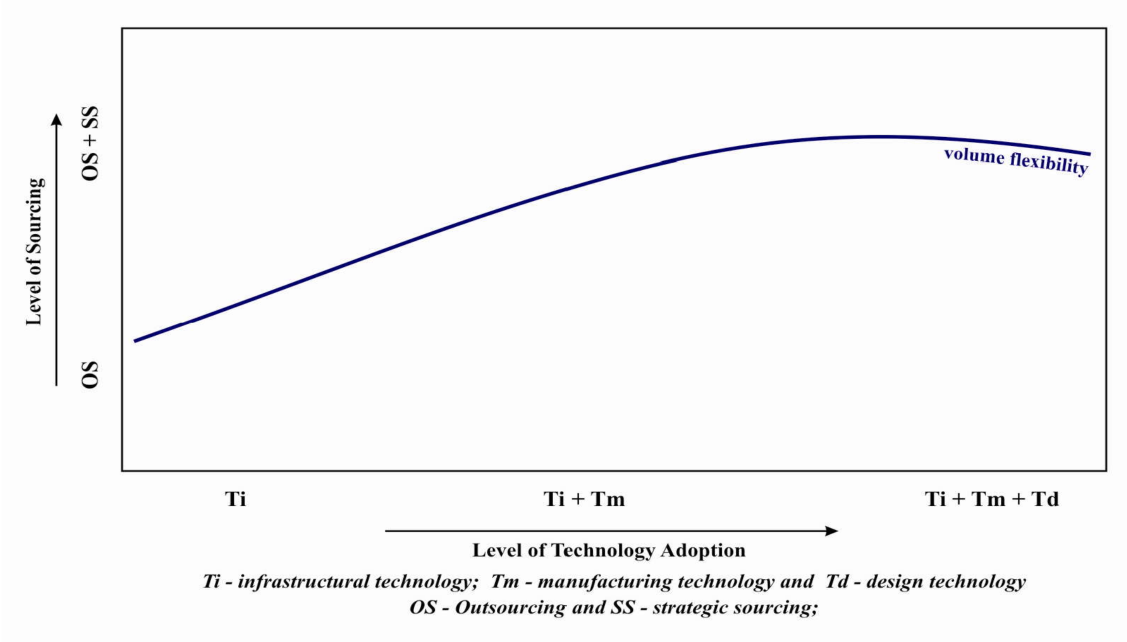


Figure 6.4 Systematic plan for technology- sourcing- volume flexibility framework

6.5.2 Preferred Approaches for achieving Modification flexibility

The following approaches have found to be significantly important in order of their occurrence for the achievement of modification flexibility.

i. Manufacturing technology based approach
ii. Strategic sourcing based approach
iii. Design technology based approach

The investment in manufacturing technology has primarily influenced the achievement of modification flexibility, closely followed by the strategic sourcing. This includes the augmentation of manufacturing facility with increased employment of advanced manufacturing technology and supplier competencies.

The potential benefits which can accrue from investments in advanced manufacturing technology, have become increasingly evident with growing global competition. AMT plays a major role in quality and flexibility improvements in large and medium scale enterprises. AMTs are a source of strategic competitive benefits, such as improved quality, greater flexibility, and cost reduction and 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. In this environment, the firms can frequently introduce new or modified 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 modification flexibility. 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. Introduction of modified products can occur more frequently through use of computer-aided manufacturing (CAM), since the manufacturing and design lead times may be shortened. Mass customization results from smarter production technology, which 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 modification flexibility.

Further the role of supplier at strategic level has largely and positively impacted the achievement of modification flexibility. The cross functional and cross organizational synergies with the suppliers have created a level of performance needed to create competitive advantage and quickly deliver modifications in existing products, processes and design. Minor product and design modifications have been accomplished through the acquisition of supplier technological and performance capabilities. In addition, the adoption of design technology has moderately augmented the organizations capability to introduce modified products with high level of flexibility.

The systematic plan for explicating the role of technology and sourcing practices for achieving modification flexibility has been developed and presented in figure 6.5. The manufacturing technology in facilitation with the employment of strategic sourcing has significantly impacted the achievement of modification flexibility. Furthermore, the impact of infrastructure technology and outsourcing has been illustrated as moderately positive in the figure. Finally, the investment in design technology in addition to the infrastructure and manufacturing technology reasonably enhance the firm ability to respond to the customers changing demands for modified products. An organization, based upon its business strategy and market requirements can manage the modification flexibility by selecting a blend of technology and sourcing based approaches.

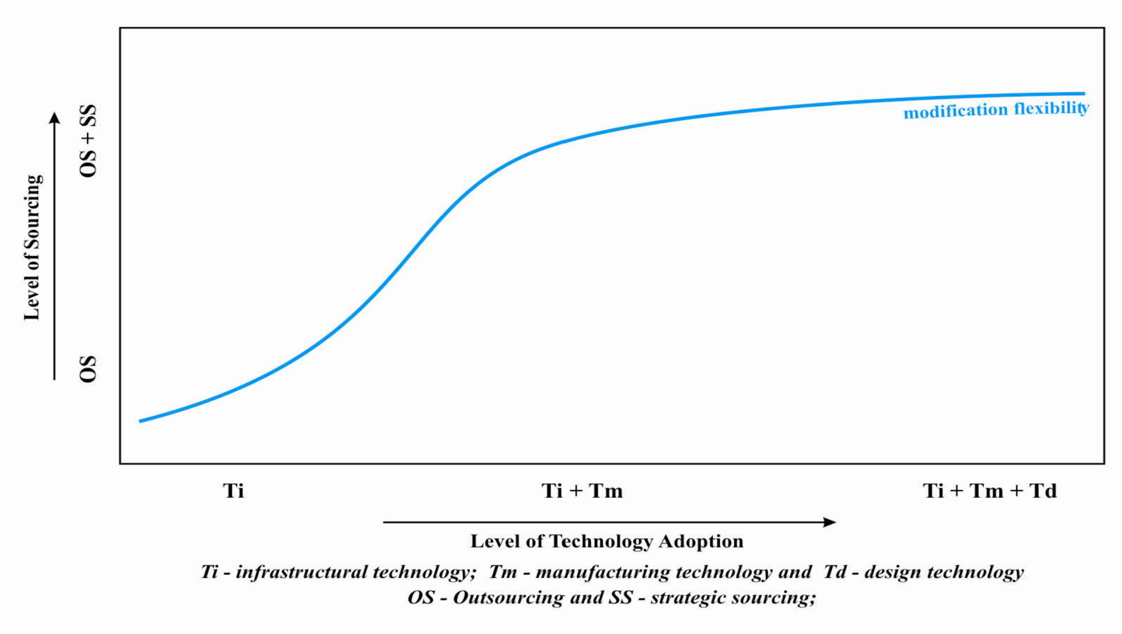


Figure 6.5 Systematic plan for technology- sourcing- modification flexibility framework

6.5.3 Preferred Approaches for achieving Delivery flexibility

The ability of an organization to respond to market changes and rapid delivery of innovative, customized products has been felt as the prerequisite for achieving delivery flexibility and flexibility competence by most of the manufacturing organizations in the era of globalization. The following approaches have been found to be significant importance in order of their occurrence for the achievement of delivery flexibility.

i. Strategic sourcing based approach
ii. Design technology based approach
iii. Infrastructural based approach

The strategic role of supplier base has emerged to be the most important aspect in achieving the delivery flexibility. The organization and the supplier share corporate incentives specific to their integrative collaboration for improving business focus, accessing world-class capabilities and accelerate re-engineering benefits under the umbrella of strategic sourcing. The organizations tend to maintain a long-term relationship and achieve delivery flexibility by involving suppliers in manufacturing as well as design and development aspects. The findings suggest that strategic sourcing may be quite important to manufacturing organizations trying to compete through delivery flexibility competence. Supplier involvement in product design and supplier responsiveness to rapid delivery of innovative products has found to benefit delivery flexibility.

Further, the investment in design technology has influenced the achievement of delivery flexibility. Introduction of new products can occur more frequently through use of computer-aided design, since the design lead times may be shortened. The design lead times and delivery of innovative products can significantly be shortened with the use of technology investment in manufacturing design. Design technologies, such as CAD, CAE, and the internet, support product design and engineering. 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. The investment in this portal of technology will lead to the development of core competencies and hence market capabilities of the organizations. Improvements in overall quality may be achieved through automated inspection and testing, better production, information and the more accurate delivery performances.

This has been followed by technology investment in manufacturing infrastructure including the explicit use of soft, administrative and intermediate technologies. These will result in strengthening the organization capabilities to handle the shortening of the overall throughput time, allowing accurate delivery performances to be achieved. These technologies such as 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 and facilitate the flexibility competence of the firm. Apart from these, the role of technology investment in manufacturing has moderately influenced the attainment of delivery flexibility. Manufacturing technologies, such as CNC, CAM, and AMHS, make production easier and faster.

The systematic plan for explicating the role of technology and sourcing practices for achieving delivery flexibility has been developed and presented in figure 6.6. The impact of strategy sourcing has been found to be of utmost importance followed by the design technology as an instrument for achieving delivery flexibility.

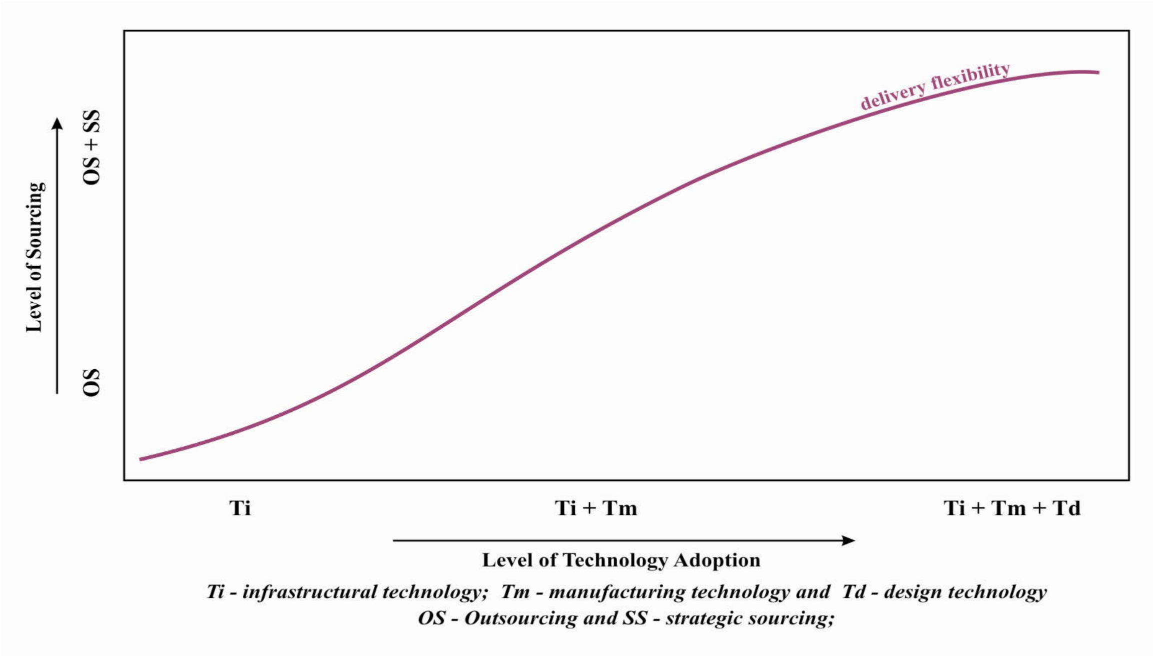


Figure 6.6 Systematic plan for technology- sourcing- delivery flexibility framework

6.5.4 Development of Technology-Sourcing -Flexibility Systematic Plan

Based upon the Hadley's matrix of cautions optimism for dominance matrices employing optimism, average, pessimistic and cautious optimism approaches, presented in Table 6.9, inferences have been evolved concerning the impact of various approaches for achieving strategic and tactical level manufacturing flexibilities. These inferences have further paved the way for the development of technology-sourcing-flexibility systematic plan.

An optimistic dominance matrix approach has brought out the role of manufacturing technology at first place followed by the strategic sourcing. Investment in infrastructural and design technologies further strengthen the capabilities of the organization to achieve manufacturing flexibilities at tactical and strategic level.

In pessimistic approach, the role of strategic sourcing has played a significant role in achieving various tactical and strategic level flexibilities. The organizations focus their business towards the virtual organizations in this type of approach, with little in house investment in high-end manufacturing and design technologies. The role of supplier consistency, flexibility, competence and strategic relationships has paved the way to the achievement of various flexibilities. The organizations in addition also focuses on the outsourcing the manufacturing facilities and investment in infrastructural technology for achieving volume flexibility. These types of the organizations are referred as assemblers in the manufacturing industry. The investment in design technology has a least priority for these types of the organizations.

However, in case of average optimism the role of strategic sourcing and manufacturing technology has significantly influenced the accomplishment of manufacturing flexibilities at tactical and strategic level. The investment in infrastructural technology, outsourcing and design technology has also been considered important in order of their occurrence.

Further, Hadley's cautious optimism for 80%, 60%, 40% and 20% optimism level dominance matrices have also been considered for the studying the impact of different approaches on different flexibility dimensions. Analysis of different optimism levels have revealed the necessity of employing the varied technology and sourcing based approaches for the achievement of volume, modification and delivery flexibility. The current market scenario for the manufacturing industry may not yield the desired result for pure optimism approach because of underdeveloped manufacturing infrastructure and constrained research opportunities in the country. The high cost of technology acquisition, meager technological capabilities and restricted indigenization has also limited its scope and implementation. Finally, pure pessimistic approach may also not expected to succeed because suppliers' integration in manufacturing and design system will lead to organizational complicacies, loss of control and confidentiality dependency. In such scenario, a cautious optimism approach with high degree of optimism has been employed.

The following approaches have found to be significantly important in order of their occurrence for the achievement of manufacturing flexibilities at tactical and strategic level.

i. Strategic sourcing based approach
ii. Manufacturing technology based approach
iii. Infrastructural technology and outsourcing based approach

There is a growing recognition of the deployment of sourcing practices for achieving the manufacturing flexibility. It is clear that sourcing has the potential to influence an organization's flexibility in responding to market demands. The role of strategic sourcing has emerged to be a key area of focus where the organizations maintains a win-win situation with their key suppliers for effectively managing manufacturing flexibility needs at tactical and strategic level. Higher level of supplier competencies in technology and allied areas in some of the processes has facilitated the strategic sourcing arrangement with key suppliers by the organizations. As a result the organizations can quickly respond to the changing market requirement, reduce time to market the new product mix and focus on strengthening their core competences. As representing a general trend, these factors expand the range of development options open to the organizations and increase the importance of the role of suppliers in the product and process development processes.

Further, the organizations must focus on the various aspects of technology, although in varied importance, for building and enhancing their core competencies. The role of manufacturing technology has been imperative for the organizations to become responsive to market fluctuations. Manufacturing technology, when properly implemented, monitored and evaluated, can improve the operating efficiency and effectiveness of the adopting organizations in terms of its manufacturing capabilities and flexibility. After putting the manufacturing technologies in place the organizations must focus on design technology through implementation of CAD/CAE and local R&D efforts for localization and indigenization of adopted technologies.

Infrastructural technology has considerably helped the organizations to integrate their operations and processes within the organizations and among the key suppliers, leading to cost reduction, enhanced flexibility and high profitability. Also, at tactical level, outsourcing of sub strategic manufacturing activities has helped the organizations to achieve flexibility at plant or tactical level.

Finally, based upon the outcome of qualitative analysis, a systematic plan for technology-sourcing-flexibility relation has been finally evolved and presented in figure 6.7, for achieving tactical and strategic level manufacturing flexibility. It has been concluded that the balanced and simultaneous use of new technology and sourcing practices has significantly helped the organizations to effectively manage the different manufacturing flexibilities. A system shift has been witnessed towards the significant and optimistic impact of strategic sourcing for managing the rapidly changing manufacturing flexibility needs. Moreover, the systematic implementation of manufacturing technology has also considerably enhance the flexibility competence of the organizations and followed by other technology and sourcing based approaches. The manufacturing organizations can follow the outcome of the proposed plan logically and sincerely for the accomplishment of business objectives related to flexibility aspect.

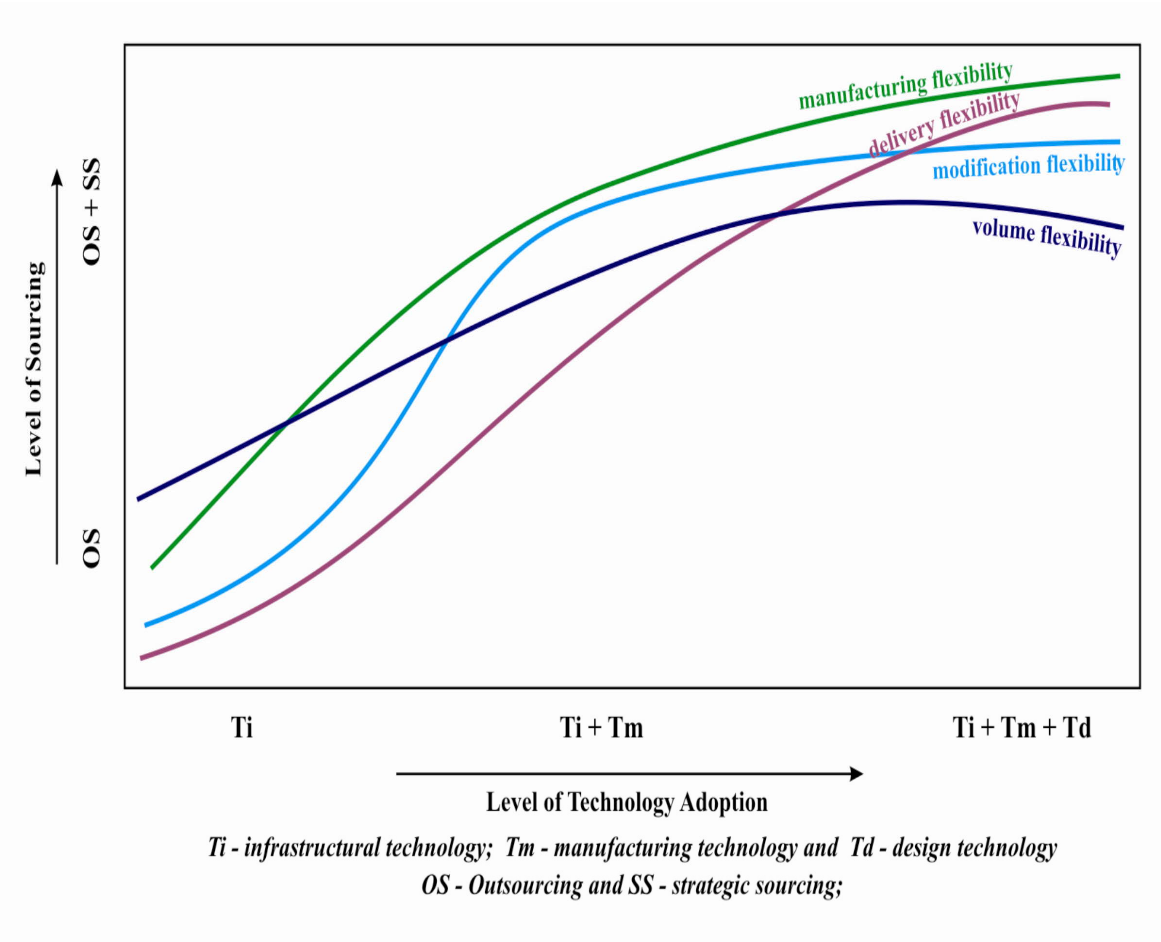


Figure 6.7 Systematic plan for technology-sourcing-flexibility framework

6.6 Concluding Remarks

The chapter presents at one place an extract of the vital essentials of this research effort especially outlining the design, conceptualization, implementation, analysis and interpretation of the results for achieving manufacturing flexibility at tactical and strategic level. Although the findings, which are based on the empirical study, case studies and qualitative modeling of medium and large scale firms are in the context of manufacturing organizations of north India, much of the implications and suggested management approaches are generic and can be applicable to manufacturing industries in India and to a little extent to other less developed countries.

CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter covers the summary of the research work, its results, conclusions, and the recommendations. The chapter also lists various areas, which can be taken up for further research. The summary of the research covers the method adopted, salient features, and tools and techniques used in the work. Further, the results of the survey and the case studies, and the inferences drawn from them along with the major learnings have been presented. Based on the results and the findings, conclusions have been drawn and recommendations have been made. The limitations along with the scope for future work are covered in the subsequent sections of the chapter.

7.2 Summary of the Research

The study has been conducted with an objective to assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities. The research has been carried out using flexible system methodology. The problem has been conceptualized as an S-A-P (Situation-Actor-Process) paradigm. Various phases of the study have been to: *clarifying the context* through a detailed review of the studies on flexibility, critique and taxonomy of manufacturing flexibilities, advanced manufacturing technology, sourcing practices and their relationships; *understanding and assessing the situation* by conducting a survey of various manufacturing organizations of north India, involved in achieving different manufacturing flexibilities using a peculiarly designed questionnaire through mail / personal visits and further analyzing the data collected through survey to establish the relationship between various independent and dependent constructs; assessing the actor's capability by critically assessing the four case studies in the surveyed manufacturing organizations, to analyze the methods/techniques/approaches adopted for achieving manufacturing flexibilities, the success achieved and the modifications made in the future plans; *synthesis of the learning issues* of survey and case studies; *developing a management process* for managing the new technology and sourcing practices in manufacturing industry; and finally *recommending a systematic implementation plan* for depicting the technology-sourcing-flexibility relationships and achieving tactical and strategic level manufacturing flexibility.

A simple, relevant and comprehensive questionnaire containing around 160 questions pertaining to the desired conceptual framework has been peculiarly designed, which seeks information on the status of different dimensions of manufacturing flexibility and various methods for achieving it in the Indian manufacturing industry. Special emphasis has been given to seek information related to business strategy and performance of the organizations, status of volume, modification delivery and manufacturing flexibility and the role of technology and sourcing practices in achieving different flexibilities. The questionnaire has been designed after extensive literature review and validated through peer review from academicians, consultants and practitioners from the industry. A 1–5 Likert-type scale has been employed for all item measures in the questionnaire. From the survey, the associations between various independent constructs and different manufacturing flexibility dimensions have been established using canonical correlation and multiple regression analysis. The primary interest in data analysis is to investigate the influence of sourcing practices and advanced manufacturing technology on manufacturing flexibilities and technology-sourcing associations.

The purpose of the case studies has been to validate the results achieved from descriptive and empirical analysis of the survey. For carrying out the case studies, the manufacturing organization should be the representative of the manufacturing industry, implementing various operations and process pertaining to the potential areas of technology and sourcing and forthcoming and co-operative in conducting the detailed case study.

Various factors related to new technology and sourcing practices as mentioned earlier have been studied through case studies. Only those factors, which were reflected as the potential factors have been taken up for detailed study. The case studies have been conducted in a phased manner starting from the evolution of the need for incorporating the manufacturing flexibility at the tactical level to the excellence at the strategic level by incorporating the new technology and sourcing practices as a competitive tool in different manufacturing enterprises. In each case study, the various aspects concerning purpose of study including; organization business strategy and initiatives, performance indicators, manufacturing capacity and capabilities, role of technology and sourcing practices, status of manufacturing flexibility, relative performance of technology and sourcing practices and social and environment aspects have been analyzed for achieving manufacturing flexibilities. Further, the success achieved, the modifications made in the future plans have been compiled and analyzed in detail. The analyzed result of the case studies depicts the total industrial scenario about the achieved level of manufacturing flexibilities and assesses the relative impact of sourcing practices and new technology on different flexibilities for providing a basis for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities.

For effectively managing the manufacturing flexibility in manufacturing industry, a management process has been developed in consultation with the experts from the industry. For this, various techniques of qualitative modeling like option field methodology, option profile methodology, analytical hierarchy process, and fuzzy set theory have been used.

Finally, an implementation plan has been worked out to effectively manage the different manufacturing flexibilities in manufacturing industry. The order of implementing various strategies for successfully achieving the different manufacturing flexibilities at tactical and strategic level in Indian context has been highlighted.

7.3 Results and Major Learnings

The various results and learning issues have been derived on the basis of descriptive and empirical analyses of the primary data collected through the questionnaire survey and case studies. These learning issues have been listed below and will be synthesized in the qualitative modeling for developing the implementation plan.

7.3.1 Learnings from the Survey

The learning issues of the descriptive and empirical study of the survey have been synthesized and given below accordingly in pursuit of effectively managing the manufacturing flexibilities.

Concerning business strategy and initiatives

- 'Customer focus and commitment' has been considered as the highly important business initiative by majority of the organizations.
- The role of 'manufacturing technology' and 'win-win situations with suppliers' has been equally and significantly targeted by 81% of the organizations.

- Organizations have largely considered the importance of inducing flexibility in the manufacturing and design as an instrument for achieving competitiveness. However, majority of organizations have given the foremost priority to the achievement of quality conformance and reliability.
- Achievement of flexibility in manufacturing has been found to be a significantly important by 75% of the organizations.
- 77% of the organizations have given a significant importance to the attainment of adjustments in production capacity quickly. Further, flexibility in offering large degree of product features and variety has been considered significantly important by 65% and introduction of rapid design changes in the products have been felt considerably important by 50% of the organizations.
- 78% of the organizations have achieved the substantial improvement in their competitive position in the recent years of their business operations.

Concerning technology adoption

- The survey results depict the mixed response for the level of adoption of new technology by the organizations.
- 68% of the organizations have an agreement that manufacturing and design technologies played a significant role in their success.
- Increase in product quality in terms of performance and features have been found to be the fundamental factor for augmenting the adopting of new technology in 90% of the organizations.
- The need to improve the flexibility in the manufacturing system and fostering of next generation technology has been the main rationale for new technology adoption in 50% of the organization.
- Adoption of Infrastructural technologies has positively influenced the competitive position in 65% of the organizations.
- High cost of new technology has been considered as a main barrier for its adoption by 70% of the organizations.
- 60% of the organizations adopt new technology in order to reduce their dependency on external suppliers.
- The lack of information on new technology and customer non-responsiveness to new products has little to moderate effect for adopting the new technology in 23% of the organizations.

- Around 85% of the organizations have considerably increased the performance and features of their products by the adoption of new technology.
- ‘Speed of delivery’ and ‘number of customized product offerings’ has significantly increased as a result of new technology adoption in 79% of the organizations.
- Tactical and strategic level flexibilities have considerably increased in 69% of the organizations as an outcome of technology adoption.
- The cost of the existing and future product innovations have shown an upward trend, which can be resulted due to the high cost of technology acquisition in short term.
- 65% organizations have revealed a moderate improvement in the market share and net profit as a result of adopting new technology.

Concerning sourcing practices

- ‘Reduction in operating cost and risk of business’ has been considered as a significant factor in 85% of the organizations and followed by ‘adaptability to customer’s needs and requirement’ for adopting the various sourcing practices.
- 60% of the organizations have an agreement that the outsourcing of manufacturing facilities has played a moderate role in their business success.
- 61% of the organizations have an agreement that an involvement of supplier(s) in design and new product development process has played a moderate role in managing the market fluctuations.
- Ability to achieve volume and modification flexibility has been significantly improved in 86% of the organizations, due to the adoption of various sourcing practices.
- ‘Delivery of innovative and customized products’ has seen a moderate upside movement due to the adoption of sourcing practices in 55% of the organizations. In addition, 50% of the organizations have seen a moderate increase in the delivery speed and reliability.
- ‘Competitive scope of the supplier’ has been considered as most important factor in the supplier selection process by most of the organizations. An organization’s ability to produce the quality products at a reasonable cost and in a timely manner has been highly influenced by its suppliers’ capabilities.
- ‘Supplier technological competencies’ has emerged as the determining factor for the organization’s success. Further, most of the organizations have considerably focused on the supplier delivery competence in terms of consistency and speed.

- Majority of the organizations strive to establish a long-term strategically managed relationship with key suppliers, which in turn have a positive impact on their performance.
- Supplier's integration in manufacturing has low to moderate impact on an organization performance in terms of loss of control and confidentiality dependency.

Concerning manufacturing flexibility

- The present status of manufacturing flexibility in the surveyed organizations is very good with an average score of 0.76 and standard deviation of 0.11 only. Status of manufacturing flexibility in 49% of the organizations is above the average value, 40% are in the fair range and poor in 11%. This can be attributed to the fact that most of the organizations have a considerable agreement to have achieved the manufacturing flexibility at the operational and tactical level but need to strengthen their capabilities at strategic level and a major improvement plan is urgently needed for effectively managing the manufacturing flexibilities.
- Most of the organizations have a capability to introduce process improvements in the manufacturing system. Further, 85% of the organizations have a capacity to produce large number of product categories in the manufacturing system.
- Around 72% of the organizations have a moderate to high capacity to handle volume changes in the manufacturing system in which 23% have a highest agreement to handle these demand fluctuations.
- 77% of the organizations believes that they can handle the different delivery sequences quickly and efficiently to satisfy customer demands and creating new markets. Around two third of the organizations can quickly changeover the manufacturing system to a different product mix.
- 60% of the organizations agree to the fact that the product configurations can be changed many times during the manufacturing process to accommodate customer preferences.
- The responsiveness of the organizations to the customer demands and operating efficiently at different levels of output has emerged as the most important, amongst flexibility-oriented tasks.
- The delivery of innovativeness in designing of new products has been an area of concern within the organizational competencies. Only 55% of the organizations have the capability to put new product design into production quickly.

- The sourcing practices are leading in flexibility, delivery and net profit aspects in contrast to new technology, which leads moderately for quality and market share.
- Cross-functional teams have been found to be the key area of interest for achieving manufacturing flexibility.

Concerning volume flexibility

- The current status of volume flexibility in the manufacturing organizations is very good with an average score of 0.76 and standard deviation of 0.10 only. Analysis of data revealed that 51.6% of the organizations are above the average value, out of which, 23.3% is in very good range and 28.3% of the organizations possess a good status.
- 79% of the organizations strongly agree that they can easily handle the demand for rapid increase in production volumes. Further, more than half of the respondent organizations have a capacity to handle the varied output volumes for the different products largely.
- In process improvement can be introduced in the manufacturing system without creating disturbances in 74% of the organizations.
- 46% of the organizations have moderate to significant impact on the profitability aspect as a result of operating at different production volumes.
- Technology investment in manufacturing infrastructure, explicitly the use of soft, administrative and intermediate technologies have resulted in strengthening the organization capabilities to handle rapid increase in production volumes and adjust the level of production quickly.
- Supplier involvement in modifying products has a significantly positive impact in managing the frequent volume fluctuations without sacrificing the quality of the different products. Also, the supplier ability to respond to order delivery changes has a positive relationship with volume flexibility.

Concerning modification flexibility

- The current status of modification flexibility in the manufacturing organizations is reasonably good with an average score of 0.74 and standard deviation of 0.10 only. 60% of the organizations are above the average value, out of which, only 15% are in very good range and 45% of the organizations possess a good status. Further, 23.3% of the organization are in fair range and possess a moderately important score.

- 81% of the organizations strongly agree that they are capable of producing minor alterations in product design to meet customization.
- 55% of the organizations have the ability to introduce a large number of new or modified parts and products frequently.
- The cost of the modified or new product and transition penalties in cost has been an area of concern for the organizations.
- Only 45% of the organizations have a reasonable facility to modify the product or product mix in a short span of time.
- The role of 'supplier involvement in modifying products', explicitly the supplier assistance in minor product and process design changes and managing the rapid changes in product variety have resulted in strengthening the organization capabilities to manage the modification flexibility.
- The strategic use of organizational infrastructural resources has shown a positive trend towards the attainment of modification flexibility.

Concerning delivery flexibility

- The present status of delivery flexibility in the manufacturing organizations is good with an average score of 0.714 and standard deviation of 0.13. Analysis of data depicts that 53.3% of the organizations are above the average value, out of which, only 13.3% is in very good range and 40% possess a good status.
- 62% organizations agree that they can handle rapid delivery of innovative products, while 47% shows their divergence to provide delivery differentiation profitably. Further, 32% of the organizations have shown a neutral response to the achievement of different item measures of delivery flexibility.
- Around 50% of the organizations have a moderate capacity to rapidly introduce the customized products for new market creation.
- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization. It has been found that the selection of supplier based on technology is important for the manufacturer whose focus is on delivery flexibility.
- The role of strategic sourcing is found to be statistically significant in developing the delivery flexibility. However, sourcing strategy for enhancing modification flexibility may have to be implemented in advance of similar actions to support the development of delivery flexibility.

- Supplier involvement in managing minor product and process changes has played an imperative role as a prerequisite in developing delivery flexibility.
- The impact of supplier competencies has been found influential for the development of delivery flexibility in an organization.
- An organization with high level of delivery flexibility can operate more economically, if it has already achieved a high level of volume flexibility.

Concerning learnings from Empirical Study

- Delivery flexibility has a strong and significant association with other dependent variables i.e. volume flexibility (r=0.671, p=0.000) and modification flexibility (r=0.706, p=0.000).
- Volume flexibility has been found to have a strong positive association with the supplier involvement in volume changes requests, SIVCR(r=0.464, p=0.00), supplier involvement in modifying products,SIMP(r=0.483, p=0.00) and technology investment in manufacturing infrastructure, TIMS(r =0.532, p= 0.00).
- Further, modification flexibility has established a significant positive association with SIVCR (r = 0.479, p = 0.00) and SIMP (r =0.435, p=0.01).
- Supplier competencies,SCOMP (r=0.550, p=0.000), SIVCR (r=0.468, p=0.000) and SIMP (r=0.451, p=0.00) has been found to be significantly associated with the delivery flexibility.
- SIMP has the highest cross-loading (0.511) among the independent variates for the set of dependent variates consisting of volume and delivery flexibility.
- SCOMP has come out to be second most significant factor affecting volume and delivery flexibility with cross loading of 0.503 and has the highest cross-loading (0.535) among the independent variates for the set of dependent variate consisting of modification and delivery flexibility.
- TMSYS and TIMS has a cross loadings of 0.334 and 0.338 respectively with a set of dependent variates consisting of modification and delivery flexibility.
- In multiple regression analyses, TIMS and SIMP have significantly influenced the achievement of volume flexibility. SIMP has found to be important for achieving modification flexibility and SCOMP and SIMP have played a major in achieving delivery flexibility.

7.3.2 Learnings from the Case Studies

The learnings from various case studies conducted in various manufacturing organizations have been synthesized as follows:

Concerning business initiatives

- Competitive excellence and commitment to quality remains the foremost business initiatives for the manufacturing organizations.
- Win-win situations with the suppliers, use of advanced manufacturing technology and flexibility in the manufacturing system are the important aspect to be looked upon in a competitive market environment.
- Cross-functional and cross-organizational teams wherever required has helped the organizations in achieving business competitiveness.
- Recognizing the potential of technology and innovation, the organizations can continuously harness the power of their knowledge capital.
- Seamlessly future proofing capital investments assures evolutionary capabilities of manufacturing infrastructure.
- Organizations have emphasized on VA/VE to cut down costs.
- For, survival, the organizations have been compelled to adopt cost cutting strategy in a big way so as to retain their profit margins. It is seen that there is a lot of scope for cost cutting through strategies like improving supply chain management, reducing inventory and making the vendors competitive.

Concerning advanced manufacturing technology

- The important factors for the implementation of AMT's includes the fostering of manufacturing flexibility, enhancing the design capabilities, improving the productivity and attain quality leadership in the market place.
- Use of IT enabled systems have largely helped the organizations to reduce the inventory level, promote E Sourcing, enhance various manufacturing flexibility, control waste and improve employee connect. Adoption of ERP system has further facilitated to perform better in the global market and manage manufacturing flexibility.
- The organizations are investing appreciable amount in new machinery and equipment and R&D to keep itself updated with the latest technology. In house R&D has helped

some of the organizations to indigenously develop robots that in course help significantly to achieve the tactical level flexibility.

- Capabilities strengthened in benchmarking and design optimization has further improved and upgraded the value of the product.
- The organizations have adopted the technology from its alliance partners to reduce the lead-time to new product introduction.
- The organizations are building core capabilities in some critical area and exploiting these to the maximum extent.
- The majority of the organizations does extensive analyses based on the trends of the past years before going in for new technology and also goes for economic viability study for adopting new technology.
- The organizations have a capacity to assess and select cost effective technology solutions.

Concerning sourcing practices

- A participative and collaborative approach with the suppliers has emerged as a key factor for the growth of any manufacturing organization.
- 'Speed of capacity changeover' and 'adaptability to customer needs and requirement' in the manufacturing system has emerged as important factors for adopting the sourcing practices.
- 'Supplier technological competences', 'improvement in product variety' and 'low delivery time' have been the important factors for adopting different sourcing practices.
- Organizations rely on small but high quality suppliers and strive to establish long-term relationship with suppliers.
- Early involvement of suppliers triggers innovations at the designing stage itself. This will further lead to achieve cost target approach at design stage itself.
- The tier-1 organizations have penetrated their facilities to become a system supplier to OEM's apart from manufacturing aspects only.
- Organizations have witnessed the marginal decrease in product cost and substantial increase in net profit as a result of adopting and developing sourcing practices.
- Supplier flexibility, technological capability and financial condition play a significant role in supplier selection criteria.

- Cross-functional and cross-organization efforts to increase flexibility and eliminate uncertainties have created the level of performance needed to create competitive advantage.
- Suppliers are being trained to evolve as innovation drivers by engaging them at new product designing stage and achieve various business parameters more efficiently and effectively.
- Some of the companies have identified a group of suppliers for implementing an ERP solution enabling seamless sharing of information and promoting e business, and flexibility as a measure for vendor consolidation.
- Longstanding strategic partnerships with key technology providers, allows the organizations to access new technologies. New technology from alliance partners helped the companies to reduce the lead-time to new product introduction and further localize it to suit market conditions within house R&D efforts.

Concerning manufacturing flexibility

- The organizations moderately rely on adoption, adaptation and further development of manufacturing technology and infrastructure in house to achieve various tactical and strategic level flexibilities.
- The significant use of design technology and strategic sourcing has helped the organizations to achieve delivery flexibility, in course leads to the introduction of new products with minimal lead-time.
- The augmentation of facilities with manufacturing technology and strategic sourcing has considerably helped the companies to achieve the modification flexibility.
- Significant investment in infrastructural technology and the involvement of vendors in providing capacity support has helped the organizations in achieving volume flexibility.
- Early involvement of suppliers for design and development and supplier competencies has impacted the achievement of delivery flexibility moderately.
- The significant use of technological and sourcing aspects helps the organizations to achieve the delivery flexibility leading to the introduction of new products with minimal lead-time.

7.3.3 Summary of Developing a Management Process

To achieve the projected requirements of managing manufacturing flexibility, a management process has been developed in consultation with the experts from the industry. For developing the management process, a qualitative modeling using option field methodology, option profile methodology, analytic hierarchy process, and fuzzy set theory has been used. The modeling began with listing of various options to manage new technology in manufacturing industry for achieving manufacturing flexibilities. These options have been derived from the synthesized learning issues of this study. Option field methodology and option profile methodology have been used as a basis for this purpose. The options have been then put into various categories and these categories have been considered as the dimensions of the design. The dimensions have been then put into broader categories called clusters. The clusters have been put into sequence based on the importance of an area. The sequencing of dimensions within the clusters has been then carried out. Various profiles for course of actions planned for new technology and sourcing practices have been finalized. These profiles are: manufacturing technology based approach, design technology based approach, infrastructural technology based approach, outsourcing based approach and strategic sourcing based approach. After deciding the profiles, the objectives of the study have been taken from the results of the survey conducted. These are: volume flexibility, modification flexibility and delivery flexibility. To find out their degree of importance, these objectives have been compared pair-wise using AHP. Following this, quantitative contribution of each profile to each objective has been determined, and position matrices have been made. From the position matrices, weighted position matrices have been determined by multiplying weight of criteria by the value of each position of position matrices. The weighted position matrices have been aggregated in three ways, i.e. optimistic, average and pessimistic aggregation. Dominance matrices have been also prepared to display dominance structure between all possible pairs of options. Based on these matrices, the ranks of options have been decided for the manufacturing industry. Different approaches have been suggested for achieving various manufacturing flexibilities at tactical and strategic level.

7.3.4 Summary of Implementation Plan

After developing the management process for managing the new technology and sourcing practices in manufacturing industry for achieving various tactical and strategic manufacturing flexibilities, a systematic implementation plan has been developed for its effective and smooth implementation. Different strategies to be followed in this regard have been discussed in Indian context. The implications of these strategies have also been pointed out.

The results of various analyses as well as the developed management process have brought out the prime importance for *'strategic sourcing based approach'* as the key strategy, to be followed for managing manufacturing flexibility at tactical and strategic level. Further *'manufacturing technology based approach'*, and *'Infrastructural technology and outsourcing based approaches'*, are the need of the hour in this dynamic and highly competitive market environment. The manufacturing organizations in the region have to follow these three strategies logically and sincerely for the accomplishment of various business objectives related to flexibility aspect.

7.4 Conclusions and Major Recommendations

This section points out conclusions, in a digest form, in light of research objective and various issues and as a result of the detailed study carried out through survey, case studies and qualitative modeling. The following conclusions have been drawn:

- Manufacturing flexibility has been viewed as a multi-level and multi-dimensional concept rather than as an independent variable. The same has been defined along with its dimensions in light of the existing literature (*Chap. 2, pp. 22, 31-32, and 38*).
- Large and systematic investments in advanced manufacturing technologies and sourcing practices have positively influenced the management of manufacturing flexibilities at tactical and strategic level. The findings suggest that the sourcing practices are leading in flexibility, delivery and net profit aspects in contrast to new technology, which leads moderately in quality and market share (*Chap. 4, pp. 109-112*).
- The following flexible approaches have been identified in the qualitative model developed during this study for managing manufacturing flexibilities broadly at tactical and strategic level: outsourcing based approach, strategic sourcing based approach, infrastructural technology based approach, manufacturing technology based approach, and design technology based approach (*Chap.6, pp. 273-274*). Further, a systematic plan for technology – sourcing – flexibility relationship has been developed for managing manufacturing flexibilities (*Chap. 6, pp. 288*).

- Based on a conceptual framework developed during this research work and subsequent study, the following inferences have been crystallized for the strategic choice between different methods of achieving manufacturing flexibilities in the manufacturing organizations (*outcome of synthesis of learning issues of survey and case studies in the domain of qualitative modeling, Chap. 6*):
  - Strategic sourcing (including joined knowledge contribution, creation of synergy and integrative interface with system suppliers) and manufacturing technology competence has significantly influenced the achievement of manufacturing flexibility at tactical and strategic level.
  - Outsourcing of manufacturing and adoption of infrastructural technologies have enhanced the capabilities of the organizations to achieve volume flexibility.
  - The systematic investment in manufacturing technology and employment of strategic sourcing has positively influenced the attainment of modification flexibility.
  - Strategic sourcing and adoption of design and manufacturing technologies have considerably ensured a higher level of delivery flexibility.
- The organizations should enlarge their technological competencies before widely adopting the supplier based sourcing practices for effectively managing the manufacturing flexibilities. The organizations should build core capabilities in some critical area and develop these to the maximum extent (*Chap. 5, pp. 249-251*).
  - Use of IT enabled systems and adoption of infrastructural technology has helped the organizations to promote E sourcing and manage the manufacturing flexibilities needs effectively.
  - In house research and development efforts have facilitated the organizations to indigenously develop manufacturing competencies, which in course improve the manufacturing flexibilities, reduce cost and control waste.
- The findings suggest that sourcing practices have positively influenced the manufacturing organizations trying to attain the flexibility competence. Organizations can deploy specific sourcing practice designed to achieve specific flexibility objectives (*Outcome of survey, Chap.4 and case studies, Chap. 5 learning issues*).
  - Organizations that place an emphasis on the use of stringent selection criteria for choosing their suppliers based on their quality, consistency, flexibility, delivery and relationship, performed better in their respective industries.

- Organization must rely on small but high quality suppliers and strives to establish long-term relationship with them.
- Cross-functional and cross-organization efforts to increase flexibility and eliminate uncertainties have created the level of performance needed to create competitive advantage and further helped the organizations in achieving business competitiveness.

- Another outcome of managerial interest is the association of different manufacturing flexibilities with one another and the role of organizations to acquire certain flexibilities as a pre-requisite for developing others. The role of delivery flexibility has been found to be the largely important, followed by modification and volume flexibility (*Chap. 6, pp.274*). This could be attributed to the fact that the organizations now a day are focused towards the delivery of new or customized products quickly for achieving competitive excellence in the dynamic business environment. However, the volume and modification flexibility must be achieved prior to delivery flexibility amongst manufacturing flexibility-oriented tasks.
- Organizations should conduct business that achieves a balance of integration of economic, environmental and social imperatives while at the same time should come up to the customers' expectation *(Chap.5, pp.249)*.

7.5 Limitations of the Study

The main limitations of this study are as follows:

- The study has been limited to large and medium scale manufacturing organizations in the northern region of the India.
- The manufacturing organizations in the study have been treated alike, irrespective of the specific requirements of various sectors.
- The study has been limited to explore and explicate the impact of new technology and sourcing practices in achieving various tactical and strategic level flexibilities only.
- As such no mathematical models or quantitative relationship has been derived to calculate the contribution of various factors in achieving different flexibilities.

7.6 Scope for Future Work

While carrying out the study and trying to list its scope, a number of areas has come to focus, where detailed research can be taken up. Such areas demanding attention, further exploration, and analysis through research work are mentioned here.

- The study presents the macro–analysis for examining the impact of new technology and sourcing practices on different manufacturing flexibilities. However, similar studies can also be carried out for analyzing the impact of these practices on other competitive priorities like quality and cost individually.
- The study can be extended to examine the role of other prominent factors like human resource, work force management practices- the relationship-oriented practices and participative leadership and delegation practices, demand management through effective manufacturing – marketing schedule sharing and forecasting efficiencies on the different manufacturing flexibilities.
- The study can be extended from manufacturing to entire value chain for effectively managing the supply chain flexibility.
- All manufacturing organizations have been treated alike, irrespective of the specific requirements of various sectors. Minor changes might have to be incorporated for effectively managing manufacturing flexibility in varying situations. Thus, sectors wise analysis can also be conducted for appropriately dealing with varying requirements of different sectors.
- The item measures identified for various constructs have been considered to be equally important in the study, however in real life situations, some item measure may be more important than the others. The study can be extended by attaching appropriate weights to these item measures through qualitative techniques.
- The present study has taken into consideration the manufacturing industry only and can be extended to other categories of industry also.

7.7 Concluding Remarks

Manufacturing flexibility is widely recognized as a critical component for achieving a competitive advantage in the marketplace. The role of technology and sourcing in managing the manufacturing flexibility at tactical and strategic level in manufacturing industry has been imperative and inseparable. However, sourcing practices lead in cost and delivery aspect in contrast to technology, which leads in quality and performance. Further, the organizations must enhance their technological competencies before going into the sourcing partnerships.

A manufacturing revolution has been well underway in the Indian economy, spurred on by the increasing presence of multinationals, scaling up of operations by the domestic companies and expanding domestic market. The sector has been averaging 9 per cent in the last four years (2004-08), with a record 12.3 per cent in 2006-07.The growing economy and industrial growth in the recent years helps the manufacturing industry to invest in new technology, facilitating the increase in flexibility, quality and delivery level and product and process design capabilities. However, still due to the persistence of organizational and infrastructural barriers, the role of research and development and investment in design engineering is limited to large scale manufacturing organizations and research institutes. Additionally, Indian companies are also becoming renowned for their adherence to global quality standards and on the path of continuously increasing its productivity levels.

The role of strategic sourcing in managing varying demands of manufacturing flexibility has emerged as a key solution for the Indian manufacturing industry in addition to outsourcing of manufacturing facilities. Optimization of the value chain , joined knowledge contribution, creation of synergy, integrative interface and joined innovative capability with the key suppliers have largely helped the manufacturing organizations for effectively managing manufacturing flexibility.

It is concluded that in a dynamic business environment, new technology and sourcing practices individually and relatively put a vital impact in managing manufacturing flexibility. The effective selection and implementation of these practices are required for not only surviving but also thriving in the technology-intensive industrial environment around the globe.

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APPENDIX – A

QUESTIONNAIRE

DEPARTMENT OF MECHANICAL ENGINEERING
Thapar Institute of Engineering and Technology
(Deemed University), Patiala

SUBJECT : REQUEST FOR FILLING UP THE QUESTIONNAIRE ON "MANUFACTURING FLEXIBILITY".

Dear Sir,

I am submitting the enclosed questionnaire for seeking your expert views for my research titled "Impact of New Technology and Sourcing Practices in Managing Manufacturing Flexibilities" in your organization. This study is a part of my Ph.D. research work at Thapar Institute of Engineering and Technology (Deemed University), Patiala, Punjab.

The objective of my research work is "To assess the relative impact of new technology and sourcing practices on different flexibilities for the trade off associated with the strategic choice between different methods of achieving manufacturing flexibilities".

This questionnaire has been designed to assess the situation of new technology and sourcing practices in managing manufacturing flexibilities in the manufacturing industry. It is being sent to actual decision makers who are at senior and medium levels of management dealing with management of manufacturing system, new technology and suppliers in day-to-day situations.

The questionnaire has been divided into various sections. In each section, questions with multiple-choice answers have been designed to facilitate answering. Please answer all the questions to fulfill the objectives of my research work.

I shall ever remain grateful to you for your help and co-operation in this regard. To show my gratitude I will be happy to provide you with a summary of the findings of this study that should help you in the assessment the level of manufacturing flexibility in your organization. Your responses will be held confidential and used for the purpose of research work only.

Thanking you in anticipation and hoping for a favorable and prompt reply.

With Kind Regards,

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ORGANIZATION PROFILE

ORGANIZATION NAME	
ORGANIZATION ADDRESS	
SURVEY RESPONDENT'S NAME AND DESIGNATION	
RESPONDENT'S E-MAIL ADDRESS	
RESPONDENT'S CONTACT NO. / FAX. NO.	
Product(s) of the organization	
Collaboration(s)/ Accreditation/ certification of the organization	

Type of organization	Large Scale		Medium Scale	
Size of the organization staff base (approx.)	< 200	201 – 500	501 – 1000	> 1000
Main area of business activity	Production unit	Distribution unit	Service unit	Others

i.	Present turnover (in crores)	< 50	50 – 100	101 – 250	251 – 500	>500
ii.	Market share	< 10%	10 - 25%	26 - 50%	51 - 75%	> 75%
iii.	Net profit (over the past two years)	Substantially decreased (> -10%)	Marginally decreased (upto - 10 %)	Remained the same	Marginally Increased (upto 10 %)	Substantially increased (> +10%)

Please tick the most appropriate option

BUSINESS STRATEGY AND PERFORMANCE

B1. Please indicate the **importance of following initiatives** in your organization.

1	Customer focus and commitment	Not important 1	Least important 2	Important 3	Very important 4	Most important 5
2	Innovation and change	1	2	3	4	5
3	Commitment to quality	1	2	3	4	5
4	Manufacturing technology	1	2	3	4	5
5	Win-win situations with suppliers	1	2	3	4	5
6	Flexibility in manufacturing	1	2	3	4	5

B2. To what extent the following **competitive priorities** are significant to your organization?

1. QUALITY						
i.	Quality planning and improvement	Indifferent 1	Important 2	Moderately important 3	Very important 4	Most important 5
ii.	Reliable quality at competitive price	1	2	3	4	5
iii.	Quality conformance	1	2	3	4	5
2. DELIVERY						
i	Provide fast deliveries	1	2	3	4	5
ii	Reduce lead time	1	2	3	4	5
3. FLEXIBILITY						
i	Adjust production capacity quickly	1	2	3	4	5
ii	Large number of product features	1	2	3	4	5
iii	Large degree of product variety	1	2	3	4	5
iv.	Rapid design changes in product	1	2	3	4	5
4. REDUCE PRODUCTION COSTS		1	2	3	4	5
5. INVESTMENT IN NEW TECHNOLOGY		1	2	3	4	5

B3. Please specify the **importance of following factors in your organization for offering new or significantly improved products**.

1	To reduce the impact of market fluctuations	Not important 1	Least important 2	Important 3	Very important 4	Most important 5
2	Access to new customers/ new market creation	1	2	3	4	5
3	Quality leadership	1	2	3	4	5
4	To gain competitive excellence	1	2	3	4	5
5	Improved production flexibility	1	2	3	4	5

B4. How will you **compare your position with competitors, concerning each of the following performance parameters** over the past two years?

1	New product introductions	Substantially declined 1	Slightly declined 2	Remained the same 3	Slightly improved 4	Substantially improved 5
2	Product features and varieties	1	2	3	4	5
3	Quality of product offered	1	2	3	4	5
4	Flexibility in manufacturing	1	2	3	4	5
5	Access to new technology	1	2	3	4	5
6	Average sales growth	1	2	3	4	5

MANUFACTURING FLEXIBILITY

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 or performance.

M1. Please indicate **to what extent you agree** with the following statements **concerning various dimensions of Manufacturing Flexibilities in your organization.**

1	The manufacturing system can quickly changeover to a different product mix	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	A large number of product categories are produced in the manufacturing system	1	2	3	4	5
3	Volume changes can be handled easily	1	2	3	4	5
4	Process improvements can be introduced in the manufacturing system	1	2	3	4	5
5	The manufacturing system can be expanded easily when needed in the long run	1	2	3	4	5
6	Manufacturing system expansions do not affect the quality levels of output	1	2	3	4	5
7	The manufacturing system can handle many different delivery sequences	1	2	3	4	5
8	The product configuration can be changed many times during the manufacturing process to accommodate customer preferences	1	2	3	4	5
9	The performance of the manufacturing system is not affected by a change in product design	1	2	3	4	5
10	The manufacturing system can put the new product design into production quickly	1	2	3	4	5
11	Machines can be re-programmed easily to take over different tasks	1	2	3	4	5
12	Employees can perform many different types of tasks	1	2	3	4	5

M2. Please indicate the **competence of your organization in managing the following manufacturing flexibility tasks**.

1	Rapid delivery of innovativeness in design of products	Very low 1	Low 2	Moderate 3	High 4	Very high 5
2	To operate efficiently at different levels of output	1	2	3	4	5
3	Improved processes and quality	1	2	3	4	5
4	Responsiveness to customer’s demand	1	2	3	4	5
5	To produce wide variety of product mix simultaneously	1	2	3	4	5
6	To adapt itself or its organizational structure to changes in business environment	1	2	3	4	5

VOLUME FLEXIBILITY *Volume flexibility corresponds to the* ***ability of manufacturing system to be operated profitable*** *(in the short term****) with various amount of volume*** *for several products without incurring negative effects (e.g. time delays, changes in performance outcomes) when switching from one operation to another.*

MV1. To what extent you agree with the following statements concerning Volume Flexibility for your organization?

1	The organization can handle rapidly increasing production volumes	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	The output volumes for the different products can be varied largely	1	2	3	4	5
3	Level of production volume can be changed quickly	1	2	3	4	5
4	Process improvement can be introduced to the manufacturing system without creating disturbances	1	2	3	4	5
5	Manufacturing system can operate profitably at different production volumes	1	2	3	4	5
6	The quality of the goods produced is not affected by changes in volume	1	2	3	4	5

MV2. Please indicate amongst the following practice(s) as adopted by your organization in achieving the Volume Flexibility.

1	Redesigning the existing manufacturing system within the available facilities	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	Investment in multipurpose machines	1	2	3	4	5
3	Automation of material handling system	1	2	3	4	5
4	Close relationship with suppliers	1	2	3	4	5
5	Any other, please specify					

MODIFICATION FLEXIBILITY *Modification Flexibility is the ability of manufacturing* ***process to customize products through minor design modifications.***

MM1. As concerned to the Modification Flexibility in your organization, to what level you agree to the following statements.

1	A large number of new or modified products are introduced each year	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	The organization is capable of producing minor alterations in product design to meet customization	1	2	3	4	5
3	The variety of modules/components used, enable many different products to be configured	1	2	3	4	5
4	The organization can accommodate the high transition penalties due to change in performance outcome	1	2	3	4	5
5	The time required to change to a modified product or product mix is short	1	2	3	4	5

MM2. Please indicate amongst the following practice(s) as adopted by your organization in achieving the Modification Flexibility.

1	Redesigning the existing manufacturing system within the available facilities	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	Adoption of new technology in manufacturing (CNC's, FMS, Robotics etc.)	1	2	3	4	5
3	Use of specialized technology and capabilities of supplier(s)	1	2	3	4	5
4	Any other, please specify					

DELIVERY FLEXIBILITY The *ability of manufacturing system to respond to or influence market changes & **enables the rapid delivery of innovativeness, customized products for new market creation**.*

MD1. To what extent you agree with the following statements concerning Delivery Flexibility for your organization?

1	The organization can handle rapid delivery of innovative products	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	The customized products for new market creation are handled easily	1	2	3	4	5
3	The performance of organization is not affected by a change in the product design	1	2	3	4	5
4	The product configuration can be changed many times during the manufacturing process to accommodate customer preferences	1	2	3	4	5
5	Organization can provide delivery differentiation profitably	1	2	3	4	5

MD2. Please indicate amongst the following practice(s) as adopted by your organization in achieving the Delivery Flexibility.

1	Adoption of new technology in manufacturing (CAM/CAE/CAPP, ROBOTICS, FMS etc.)	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	Adoption of new technology for the new product design and development (CAD/ MRP/MRP II etc.)	1	2	3	4	5
3	Involvement of external suppliers in manufacturing	1	2	3	4	5
4	Cross functional teams with external suppliers for innovation in product design	1	2	3	4	5
5	Adoption of various administrative approaches (ERP, Office Automation (OA) etc.)	1	2	3	4	5
6	Any other, please specify					

NEW TECHNOLOGY *is a product or process that an organization has not previously used in their operation.*

TECHNOLOGY ADOPTION: *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.*

T1. To what extent the following factors are important in your organization **regarding the adoption of new technology**.

1	To improve flexibility in the manufacturing system	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	To reduce the dependency on external suppliers	1	2	3	4	5
3	Development / fostering of next generation technology	1	2	3	4	5
4	To improve productivity	1	2	3	4	5
5	To improve product quality	1	2	3	4	5

T2. Please indicate the **level of adoption of new technology in the following areas** in your organization.

1	Computer aided manufacturing (CAM)	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	Computer aided design(CAD)	1	2	3	4	5
3	Computer aided engineering(CAE)	1	2	3	4	5
4	Robotics and Group technology	1	2	3	4	5
5	Computerized numerical control machines(CNC's)	1	2	3	4	5
6	Flexible manufacturing system(FMS)	1	2	3	4	5
7	Soft technologies (MRP, MRPII and JIT etc)	1	2	3	4	5
8	Automatic material handling systems	1	2	3	4	5
9	Administrative approaches (ERP, OA)	1	2	3	4	5

T3. Please indicate the level of agreement for the following factors **as barriers to the adoption of new technology in your organization.**

1	High cost of new technology acquisition	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	Lack of information on markets and technology	1	2	3	4	5
3	Lack of customers' responsiveness to new products	1	2	3	4	5

T4. Please indicate the **level of change** in the following performance objectives **due to the adoption of new technology in your organization**.

1. PRODUCT QUALITY						
i.	Performance of products	Significantly decreased 1	Moderately decreased 2	Remained the same 3	Moderately increased 4	Significantly increased 5
ii.	Features of products	1	2	3	4	5
2. DELIVERY						
i.	Speed of delivery	1	2	3	4	5
ii.	Number of customized product offered	1	2	3	4	5
iii.	New product lead time	1	2	3	4	5
3. COST						
i.	Production cost	1	2	3	4	5
ii.	Cost of future product innovations	1	2	3	4	5
4. FLEXIBILITY						
i.	Variety of products	1	2	3	4	5
ii.	Delivery of innovative products	1	2	3	4	5
iii.	Capacity to change product volume	1	2	3	4	5
5. RELATIVE MARKET SHARE		1	2	3	4	5
6. NET PROFIT		Substantially decreased (> -10%)	Marginally decreased (upto - 10 %)	Remained the same	Marginally Increased (upto 10 %)	Substantially increased (> +10%)

OUTSOURCING

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.

STRATEGIC SOURCING

In strategic sourcing, 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).

OUTSOURCING AND STRATEGIC SOURCING ARE CATEGORIZED AS SUPPLIER BASED SOURCING PRACTICES

S1.Please indicate the **importance of following factors for adopting various supplier based sourcing practices** in your organization.

1	Adaptability to customer needs and requirement	Not important 1	Least important 2	Important 3	Very important 4	Most important 5
2	Speed of capacity changeover in manufacturing system	1	2	3	4	5
3	Organization can focus on core activities like newly designed innovative products	1	2	3	4	5
4	Improvement in delivery of product variety	1	2	3	4	5
5	Easy access to new technology and low delivery time	1	2	3	4	5
6	Reduce operating cost and risk of business	1	2	3	4	5

S2. Please indicate the level of the **suppliers' involvement** in managing market fluctuations in your organization.

1	Purchase of standardized parts from suppliers	Not at all 1	To some extent 2	To moderate extent 3	To a large extent 4	To full extent 5
2	Involvement of supplier(s) in manufacturing	1	2	3	4	5
3	Involvement of supplier(s) in design and new product development process	1	2	3	4	5

S3. To what extent the following competitive factors are significant in setting up **the supplier selection criteria** for your organization.

1. FINANCES						
i.	Financial conditions of the supplier	Indifferent 1	Important 2	Moderately important 3	Very important 4	Most important 5
ii.	Profitability of supplier	1	2	3	4	5
2. FLEXIBILITY						
i.	Supplier responsiveness to demand fluctuations *(volume changes, capacity etc.)*	1	2	3	4	5
iii.	Supplier modification capabilities	1	2	3	4	5
iv.	Supplier integration in design	1	2	3	4	5
3. TECHNOLOGICAL CAPABILITY						
i.	Design and innovative capabilities of supplier	1	2	3	4	5
ii.	Technological competence	1	2	3	4	5
4. CONSISTENCY						
i.	Conformance to quality	1	2	3	4	5
ii.	Consistent delivery and short delivery time	1	2	3	4	5
5. RELATIONSHIP						
i.	Length of relationship	1	2	3	4	5
ii.	Level of cooperation	1	2	3	4	5
6. COMPETITIVE SCOPE OF SUPPLIER		1	2	3	4	5

S4. Please mention the **level of agreement or disagreement** with the following statements regarding **buyer – supplier management orientation.**

1	Our organization strive to establish long term relationship with suppliers	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
2	Organization rely on small but high quality suppliers	1	2	3	4	5
3	Suppliers integration in manufacturing system will leads to organizational complicacies, loss of control and confidentiality dependency	1	2	3	4	5

S5. **How flexible are your suppliers in terms of managing the market fluctuations** for the following factors in your organization.

1	Rapid change in product volume	Inflexible 1	Less flexible 2	Moderately flexible 3	Highly flexible 4	Totally flexible 5
2	Rapid change in product variety	1	2	3	4	5
3	Delivery of innovative products	1	2	3	4	5

S6. Please indicate the **level of change in the following performance objectives due to the adoption of various supplier based sourcing practices** in your organization.

1. PRODUCT QUALITY						
i.	Process capabilities	Significantly decreased 1	Moderately decreased 2	Remained the same 3	Moderately increased 4	Significantly increased 5
ii.	Quality conformance	1	2	3	4	5
2. DELIVERY						
i.	Delivery reliability	1	2	3	4	5
ii.	Speed of delivery	1	2	3	4	5
3. FLEXIBILITY						
i.	Variety of product offerings	1	2	3	4	5
ii.	Delivery of innovative products	1	2	3	4	5
iii.	Capacity to change product volume	1	2	3	4	5
4. ORGANIZATION IMAGE AND GOODWILL		1	2	3	4	5
5. PRODUCT COST		Substantially decreased (> -10%) 1	Marginally decreased (upto - 10 %) 2	Remained the same 3	Marginally increased (upto 10 %) 4	Substantially increased (> +10%) 5
6. NET PROFIT		1	2	3	4	5
7. EFFECT ON MARKET SHARE		1	2	3	4	5

S7. Compared with the organization's major competitors, how early do you adopt the following practices for incorporating flexibility in the manufacturing system?

1	Involvement of suppliers in the manufacturing	Very late 1	Late 2	At same pace 3	Early 4	Very early 5
2	Involvement of suppliers in design and development	1	2	3	4	5
3	Investment in new technology at operational level *(for managing the market fluctuations in demand)*	1	2	3	4	5
4	Investment in new technology at organization level *(enabling the rapid delivery of innovativeness)*	1	2	3	4	5

S8. How satisfied has your organization been with the **overall performance of new technology and supplier based sourcing practices in managing manufacturing flexibilities?**

i.	Adoption of new technology	Highly dissatisfied	Moderately dissatisfied	Indifferent	Moderately satisfied	Highly satisfied
ii.	Supplier based sourcing practices	Highly dissatisfied	Moderately dissatisfied	Indifferent	Moderately satisfied	Highly satisfied

S9. As a concluding remark, please signify **the level of dependency on different sourcing practices for achieving the various manufacturing flexibilities** in your organization.

Sourcing Practice →	**OUTSOURCING OF MANUFACTURING**					**STRATEGIC SOURCING** *(outsourcing the in-house core competencies)*					**ADOPTION OF NEW TECHNOLOGY IN - HOUSE**				
1 - Not dependent, 2 - Least dependent, 3 - Moderately dependent, 4 - Highly dependent ,5 – Fully dependent															
VOLUME FLEXIBILITY	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
MODIFICATION FLEXIBILITY	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
DELIVERY FLEXIBILITY	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

THANKS FOR YOUR COOPERATION

Signature with seal of organization

APPENDIX - B

DESCRIPTIVE STATISTICS

Company	SIVCR	SIMP	SIDCR	SCOMP	SREL	TMSYS	TDE	TIMS	VF	MF	DF
1	0.80	0.70	0.64	0.73	1.00	0.60	0.53	0.27	0.73	0.77	0.71
2	0.65	0.55	0.44	0.70	0.87	0.60	0.45	0.47	0.64	0.63	0.71
3	0.75	0.70	0.76	0.80	0.87	0.70	0.58	0.60	0.80	0.74	0.80
4	0.75	0.75	0.56	0.67	0.93	0.60	0.38	0.40	0.62	0.77	0.71
5	0.55	0.55	0.48	0.52	0.60	0.60	0.33	0.67	0.73	0.67	0.51
6	0.90	0.80	0.64	0.73	1.00	0.60	0.40	0.67	0.71	0.74	0.74
7	0.75	0.70	0.76	0.80	0.87	0.70	0.58	0.60	0.80	0.74	0.80
8	0.90	0.80	0.64	0.73	1.00	0.60	0.40	0.67	0.71	0.74	0.74
9	0.85	0.85	0.68	0.93	0.93	0.70	0.68	0.60	0.82	0.69	0.60
10	0.90	0.85	0.92	1.00	1.00	1.00	0.95	1.00	0.82	0.89	0.83
11	0.60	0.70	0.92	0.83	0.73	0.60	0.70	0.73	0.69	0.60	0.74
12	0.80	0.75	0.64	0.73	0.80	0.80	0.70	0.47	0.78	0.69	0.80
13	0.85	0.85	0.87	0.97	1.00	0.80	0.67	0.80	0.76	0.60	0.57
14	0.70	0.55	0.28	0.93	1.00	0.40	0.58	0.67	0.91	0.89	1.00
15	0.80	0.75	0.76	0.77	0.80	0.80	0.63	0.80	0.78	0.83	0.80
16	0.60	0.60	0.60	0.67	0.87	0.70	0.33	0.60	0.69	0.71	0.57
17	0.75	0.75	0.84	0.87	0.93	1.00	0.68	0.67	0.78	0.83	0.77
18	0.90	1.00	0.96	0.93	1.00	1.00	0.85	0.87	0.91	0.93	0.88
19	0.60	0.70	0.56	0.73	0.87	0.60	0.63	0.67	0.62	0.63	0.54
20	0.80	0.75	0.40	0.83	0.87	1.00	0.68	0.80	0.87	0.77	0.77
21	0.70	0.75	0.60	0.77	0.80	0.80	0.68	0.60	0.87	0.71	0.86
22	0.75	0.90	0.88	0.90	1.00	1.00	0.85	0.87	0.91	0.76	0.86
23	0.70	0.75	0.48	0.73	1.00	0.50	0.50	0.33	0.69	0.66	0.77
24	0.70	0.55	0.28	0.93	1.00	0.40	0.58	0.67	0.91	0.89	1.00
25	0.60	0.60	0.60	0.67	0.87	0.70	0.33	0.60	0.69	0.71	0.57
26	0.60	0.70	0.56	0.73	0.87	0.60	0.63	0.67	0.62	0.63	0.54
27	0.50	0.70	0.56	0.60	0.67	0.60	0.63	0.67	0.67	0.77	0.51
28	0.85	0.65	0.56	0.95	0.93	0.20	0.31	0.73	0.78	0.70	0.77
29	0.75	0.75	0.68	0.73	0.80	0.70	0.68	0.73	0.73	0.63	0.63
30	0.70	0.75	0.48	0.73	1.00	0.50	0.50	0.33	0.69	0.66	0.77
31	0.60	0.65	0.36	0.73	0.80	0.60	0.55	0.47	0.71	0.74	0.71
32	0.45	0.70	0.60	0.43	0.67	0.50	0.65	0.47	0.73	0.43	0.46
33	0.85	0.90	0.84	0.87	1.00	1.00	0.95	0.93	0.82	0.80	0.74
34	0.80	0.80	0.80	0.67	0.73	1.00	0.70	0.87	0.82	0.89	0.71

Company	SIVCR	SIMP	SIDCR	SCOMP	SREL	TMSYS	TDE	TIMS	VF	MF	DF
35	0.90	0.90	0.84	0.87	0.87	0.80	0.93	0.80	0.96	0.89	0.97
36	0.90	0.90	0.64	0.75	1.00	0.20	0.60	0.73	0.98	1.00	0.91
37	0.70	0.70	0.72	0.63	0.73	0.70	0.70	0.73	0.71	0.77	0.74
38	0.90	0.75	0.84	0.90	0.80	1.00	0.80	0.93	0.87	0.94	0.77
39	0.75	0.65	0.68	0.77	0.80	0.80	0.70	0.80	0.67	0.77	0.60
40	0.60	0.65	0.36	0.73	0.80	0.60	0.55	0.47	0.71	0.74	0.71
41	0.85	0.95	0.84	0.93	1.00	0.90	0.60	0.60	0.76	0.83	0.86
42	0.70	0.70	0.68	0.83	1.00	0.80	0.73	0.53	0.53	0.69	0.60
43	0.75	0.70	0.48	0.67	0.80	0.40	0.45	0.80	0.80	0.74	0.66
44	0.75	0.85	0.80	0.90	0.80	1.00	0.90	0.80	1.00	0.90	0.83
45	0.80	0.65	0.68	0.73	1.00	0.80	0.40	0.40	0.62	0.74	0.51
46	0.90	0.85	0.84	0.93	1.00	1.00	0.70	0.93	0.80	0.77	0.80
47	0.65	0.65	0.56	0.60	0.60	0.30	0.33	0.47	0.53	0.77	0.77
48	0.85	0.75	0.64	0.80	0.73	0.80	0.73	0.87	0.78	0.74	0.74
49	0.65	0.65	0.52	0.67	0.80	1.00	0.40	0.27	0.71	0.71	0.60
50	0.80	0.70	0.68	0.70	0.80	0.70	0.65	0.93	0.87	0.80	0.71
51	0.85	0.75	0.76	0.67	0.87	0.70	0.70	0.87	0.89	0.80	0.66
52	0.85	0.75	0.72	0.83	0.80	0.90	0.75	0.80	0.87	0.74	0.74
53	0.80	0.90	0.93	0.83	0.80	0.20	0.53	0.73	0.87	0.71	0.83
54	0.80	0.40	0.64	0.77	0.80	0.40	0.53	0.73	0.56	0.43	0.40
55	0.60	0.65	0.56	0.68	0.60	0.50	0.53	0.33	0.69	0.69	0.60
56	0.75	0.75	0.48	0.77	1.00	0.40	0.65	0.60	0.69	0.63	0.60
57	0.85	0.95	0.84	0.93	1.00	0.90	0.60	0.60	0.76	0.83	0.86
58	0.70	0.70	0.68	0.83	1.00	0.80	0.73	0.53	0.53	0.69	0.60
59	0.90	0.85	0.84	0.93	1.00	1.00	0.70	0.93	0.80	0.77	0.80
60	0.75	0.75	0.48	0.77	1.00	0.40	0.65	0.60	0.69	0.63	0.60
Mean	0.75	0.74	0.66	0.78	0.87	0.69	0.61	0.66	0.76	0.74	0.72
Minimum	0.45	0.40	0.28	0.43	0.60	0.20	0.31	0.27	0.53	0.43	0.40
Maximum	0.90	1.00	0.96	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00
Range	0.45	0.60	0.68	0.57	0.40	0.80	0.64	0.73	0.47	0.57	0.60
Standard Deviation	0.11	0.11	0.17	0.12	0.12	0.23	0.16	0.18	0.11	0.11	0.13
Variance	0.01	0.01	0.03	0.01	0.01	0.05	0.03	0.03	0.01	0.01	0.02
Skewness	-0.54	-0.10	-0.23	-0.32	-0.56	-0.32	-0.03	-0.34	0.00	-0.34	-0.10

APPENDIX C

SPSS OUTPUT FOR BIVARIATE CORRELATION

Pearson Correlation Matrix

		SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS	VF	MF	DF
SIVCR	**Coeff.**	1	.588**	.519**	.634**	.527**	.308*	.350**	.514**	.464**	.479**	.468**
	Sig.		.000	.000	.000	.000	.017	.006	.000	.000	.000	.000
SIMP	**Coeff.**	.588**	1	.659**	.462**	.386**	.413**	.543**	.368**	.483**	.435**	.451**
	Sig.	.000		.000	.000	.002	.001	.000	.004	.000	.001	.000
SIDCR	**Coeff.**	.519**	.659**	1	.414**	.122	.532**	.537**	.522**	.276*	.244	.177
	Sig.	.000	.000		.001	.353	.000	.000	.000	.033	.060	.175
SCOMP	**Coeff.**	.634**	.462**	.414**	1	.615**	.346**	.491**	.434**	.419**	.388**	.550**
	Sig.	.000	.000	.001		.000	.007	.000	.001	.001	.002	.000
SREL	**Coeff.**	.527**	.386**	.122	.615**	1	.128	.136	.044	.119	.211	.317*
	Sig.	.000	.002	.353	.000		.329	.301	.739	.365	.105	.014
TDE	**Coeff.**	.308*	.413**	.532**	.346**	.128	1	.565**	.358**	.237	.328*	.121
	Sig.	.017	.001	.000	.007	.329		.000	.005	.068	.010	.359
TMSYS	**Coeff.**	.350**	.543**	.537**	.491**	.136	.565**	1	.580**	.473**	.306*	.296*
	Sig.	.006	.000	.000	.000	.301	.000		.000	.000	.017	.022
TIMS	**Coeff.**	.514**	.368**	.522**	.434**	.044	.358**	.580**	1	.532**	.378**	.248
	Sig.	.000	.004	.000	.001	.739	.005	.000		.000	.003	.056
VF	**Coeff.**	.464**	.483**	.276*	.419**	.119	.237	.473**	.532**	1	.620**	.671**
	Sig.	.000	.000	.033	.001	.365	.068	.000	.000		.000	.000
MF	**Coeff.**	.479**	.435**	.244	.388**	.211	.328*	.306*	.378**	.620**	1	.706**
	Sig.	.000	.001	.060	.002	.105	.010	.017	.003	.000		.000
DF	**Coeff.**	.468**	.451**	.177	.550**	.317*	.121	.296*	.248	.671**	.706**	1
	Sig.	.000	.000	.175	.000	.014	.359	.022	.056	.000	.000	

** Correlation is significant at the 0.01 levels.
* Correlation is significant at the 0.05 levels.

APPENDIX – D

SPSS OUTPUT OF CANONICAL CORRELATION

Dependent Variable: VF, MF, DF
Independent Variables: SIVCR, SIMP, SIDCR, SCOMP, TMSYS, TIMS

Correlations for Set-1

	SIVCR	SIMP	SIDCR	SCOMP	TMSYS	TIMS
SIVCR	1.0000	.5879	.5194	.6344	.3504	.5143
SIMP	.5879	1.0000	.6588	.4622	.5426	.3684
SIDCR	.5194	.6588	1.0000	.4138	.5373	.5218
SCOMP	.6344	.4622	.4138	1.0000	.4907	.4341
TMSYS	.3504	.5426	.5373	.4907	1.0000	.5804
TIMS	.5143	.3684	.5218	.4341	.5804	1.0000

Correlations for Set-2

	VF	MF	DF
VF	1.0000	.6200	.6709
MF	.6200	1.0000	.7058
DF	.6709	.7058	1.0000

Correlations Between Set-1 and Set-2

	VF	MF	DF
SIVCR	.4640	.4786	.4680
SIMP	.4828	.4345	.4505
SIDCR	.2756	.2445	.1773
SCOMP	.4188	.3880	.5503
TMSYS	.4728	.3063	.2963
TIMS	.5323	.3777	.2481

Canonical Correlations

1	.695
2	.530
3	.179

Test that remaining correlations are zero:

	Wilk's	Chi-SQ	DF	Sig.
1	.360	55.243	18.000	.000
2	.696	19.585	10.000	.033
3	.968	1.762	4.000	.780

Standardized Canonical Coefficients for Set-1

	1	2	3
SIVCR	-.245	-.021	-1.025
SIMP	-.605	.170	.040
SIDCR	.534	-.126	-.381
SCOMP	-.192	.976	.555
TMSYS	-.150	-.272	.614
TIMS	-.485	-.767	.146

Raw Canonical Coefficients for Set-1

	1	2	3
SIVCR	-.438	-.037	-1.833
SIMP	-1.071	.301	.070

SIDCR	.643	-.152	-.459
SCOMP	-.330	1.677	.953
TMSYS	-.190	-.344	.775
TIMS	-.533	-.842	.161

Standardized Canonical Coefficients for Set-2

	1	2	3
VF	-.694	-.916	.807
MF	-.244	-.411	-1.390
DF	-.171	1.491	.408

Raw Canonical Coefficients for Set-2

	1	2	3
VF	-1.271	-1.676	1.477
MF	-.456	-.769	-2.600
DF	-.261	2.275	.623

Canonical Loadings for Set-1

	1	2	3
SIVCR	-.747	.143	-.557
SIMP	-.746	.096	-.170
SIDCR	-.405	-.167	-.251
SCOMP	-.690	.523	.130
TMSYS	-.653	-.221	.429
TIMS	-.725	-.515	.032

Cross Loadings for Set-1

	1	2	3
SIVCR	-.519	.076	-.100
SIMP	-.518	.051	-.031
SIDCR	-.281	-.089	-.045
SCOMP	-.480	.277	.023
TMSYS	-.454	-.117	.077
TIMS	-.504	-.273	.006

Canonical Loadings for Set-2

	1	2	3
VF	-.961	-.170	.219
MF	-.796	.073	-.602
DF	-.810	.586	-.031

Cross Loadings for Set-2

	1	2	3
VF	-.668	-.090	.039
MF	-.553	.039	-.108
DF	-.563	.311	-.006

Redundancy Analysis:

Proportion of Variance of Set-1 Explained by Its Own Can. Var.

	Prop Var
CV1-1	.451
CV1-2	.108
CV1-3	.101

Proportion of Variance of Set-1 Explained by Opposite Can.Var.

	Prop Var
CV2-1	.218
CV2-2	.030
CV2-3	.003

Proportion of Variance of Set-2 Explained by Its Own Can. Var.

	Prop Var
CV2-1	.737
CV2-2	.126
CV2-3	.137

Proportion of Variance of Set-2 Explained by Opposite Can. Var.

	Prop Var
CV1-1	.356
CV1-2	.035
CV1-3	.004

APPENDIX – E

SPSS OUTPUT OF MULTIPLE LINEAR REGRESSION ANALYSES
(ENTER METHOD)

Dependent Variable: VF
Independent Variables: SIMP, SCOMP, TIMS

Descriptive Statistics

	Mean	Std. Deviation	N
VF	3.7870	.54636	60
SIMP	3.6875	.56491	60
SCOMP	3.8978	.58236	60
TIMS	3.3108	.91049	60

Correlations

		VF	SIMP	SCOMP	TIMS
Coeff	**VF**	1.000	.483	.419	.532
	SIMP	.483	1.000	.462	.368
	SCOMP	.419	.462	1.000	.434
	TIMS	.532	.368	.434	1.000
Sig. 1-tailed	**VF**	.	.000	.000	.000
	SIMP	.000	.	.000	.002
	SCOMP	.000	.000	.	.000
	TIMS	.000	.002	.000	.

Variables Entered/Removed (b)

Model	Variables Entered	Variables Removed	Method
1	TIMS, SIMP, SCOMPa	.	Enter

a All requested variables entered.
b Dependent Variable: VF

Model Summary (b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.624a	.389	.357	.43825	1.854

a Predictors: Constant, TIMS, SIMP, SCOMP
b Dependent Variable: VF

ANOVA (b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.856	3	2.285	11.899	.000a
	Residual	10.756	56	.192		
	Total	17.612	59			

a Predictors: Constant, TIMS, SIMP, SCOMP
b Dependent Variable: VF

Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	Constant	1.566	.445		3.520	.001		
	SIMP	.279	.116	.288	2.394	.020	.752	1.330
	SCOMP	.116	.117	.124	.997	.323	.706	1.417
	TIMS	.223	.071	.372	3.140	.003	.776	1.289

a Dependent Variable: VF

Coefficient Correlations (a)

Model			TIMS	SIMP	SCOMP
1	Correlations	TIMS	1.000	-.210	-.320
		SIMP	-.210	1.000	-.361
		SCOMP	-.320	-.361	1.000
	Covariances	TIMS	.005	-.002	-.003
		SIMP	-.002	.014	-.005
		SCOMP	-.003	-.005	.014

a Dependent Variable: VF

APPENDIX – F

SPSS OUTPUT OF MULTIPLE LINEAR REGRESSION ANALYSES
(STEP-WISE METHOD)

Dependent Variable: VF

Independent Variables: SIVCR, SIMP, SIDCR, SCOMP, SREL, TDE, TMSYS, TIMS

Descriptive Statistics

	Mean	Std. Deviation	N
VF	3.7870	.54636	60
SIVCR	3.7542	.55900	60
SIMP	3.6875	.56491	60
SIDCR	3.2800	.82968	60
SCOMP	3.8978	.58236	60
SREL	4.3720	.59539	60
TDE	3.4583	1.13231	60
TMSYS	3.0602	.79177	60
TIMS	3.3108	.91049	60

Correlations

		VF	SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS
Pearson Correlation	VF	1.000	.464	.483	.276	.419	.119	.237	.473	.532
	SIVCR	.464	1.000	.588	.519	.634	.527	.308	.350	.514
	SIMP	.483	.588	1.000	.659	.462	.386	.413	.543	.368
	SIDCR	.276	.519	.659	1.000	.414	.122	.532	.537	.522
	SCOMP	.419	.634	.462	.414	1.000	.615	.346	.491	.434
	SREL	.119	.527	.386	.122	.615	1.000	.128	.136	.044
	TDE	.237	.308	.413	.532	.346	.128	1.000	.565	.358
	TMSYS	.473	.350	.543	.537	.491	.136	.565	1.000	.580
	TIMS	.532	.514	.368	.522	.434	.044	.358	.580	1.000
Sig. (1-tailed)	VF	.	.000	.000	.017	.000	.183	.034	.000	.000
	SIVCR	.000	.	.000	.000	.000	.000	.008	.003	.000
	SIMP	.000	.000	.	.000	.000	.001	.001	.000	.002
	SIDCR	.017	.000	.000	.	.001	.176	.000	.000	.000
	SCOMP	.000	.000	.000	.001	.	.000	.003	.000	.000
	SREL	.183	.000	.001	.176	.000	.	.164	.151	.369
	TDE	.034	.008	.001	.000	.003	.164	.	.000	.002
	TMSYS	.000	.003	.000	.000	.000	.151	.000	.	.000
	TIMS	.000	.000	.002	.000	.000	.369	.002	.000	.

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	TIMS	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	SIMP	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

3	SIDCR	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: VF

Model Summary(f)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.532(a)	.283	.271	.46649	
2	.615(b)	.378	.357	.43823	
3	.656(c)	.430	.400	.42332	1.875

a Predictors: (Constant), TIMS
b Predictors: (Constant), TIMS, SIMP
c Predictors: (Constant), TIMS, SIMP, SIDCR
d Dependent Variable: VF

ANOVA (f)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.991	1	4.991	22.934	.000(a)
	Residual	12.621	58	.218		
	Total	17.612	59			
2	Regression	6.665	2	3.333	17.354	.000(b)
	Residual	10.946	57	.192		
	Total	17.612	59			
3	Regression	7.577	3	2.526	14.094	.000(c)
	Residual	10.035	56	.179		
	Total	17.612	59			

a Predictors: (Constant), TIMS
b Predictors: (Constant), TIMS, SIMP
c Predictors: (Constant), TIMS, SIMP, SIDCR
d Dependent Variable: VF

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.729	.229		11.924	.000		
	TIMS	.319	.067	.532	4.789	.000	1.000	1.000
2	(Constant)	1.789	.384		4.657	.000		
	TIMS	.246	.067	.410	3.651	.001	.864	1.157
	SIMP	.321	.109	.332	2.953	.005	.864	1.157
3	(Constant)	1.655	.376		4.403	.000		
	TIMS	.310	.071	.517	4.366	.000	.727	1.376
	SIMP	.493	.130	.510	3.799	.000	.565	1.769
	SIDCR	-.217	.096	-.330	-2.255	.028	.476	2.101

a Dependent Variable: VF

Excluded Variables(f)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	SIVCR	.259(a)	2.050	.045	.262	.735	1.360	.735
	SIMP	.332(a)	2.953	.005	.364	.864	1.157	.864

	SIDCR	-.003(a)	-.022	.982	-.003	.728	1.374	.728
	SCOMP	.231(a)	1.917	.060	.246	.812	1.232	.812
	SREL	.096(a)	.859	.394	.113	.998	1.002	.998
	TDE	.054(a)	.449	.655	.059	.872	1.147	.872
	TMSYS	.247(a)	1.847	.070	.238	.663	1.508	.663
2	SIVCR	.105(b)	.745	.459	.099	.552	1.812	.552
	SIDCR	-.330(b)	-2.255	.028	-.289	.476	2.101	.476
	SCOMP	.124(b)	.997	.323	.132	.706	1.417	.706
	SREL	-.032(b)	-.279	.781	-.037	.840	1.190	.727
	TDE	-.059(b)	-.499	.620	-.067	.780	1.281	.774
3	TMSYS	.102(b)	.712	.479	.095	.538	1.859	.538
	SIVCR	.127(c)	.934	.354	.125	.549	1.821	.474
	SCOMP	.135(c)	1.129	.264	.151	.705	1.419	.475
	SREL	-.073(c)	-.654	.516	-.088	.819	1.221	.464
	TDE	.025(c)	.204	.839	.028	.702	1.425	.428
	TMSYS	.138(c)	1.001	.321	.134	.531	1.882	.470

a Predictors in the Model: (Constant), TIMS
b Predictors in the Model: (Constant), TIMS, SIMP
c Predictors in the Model: (Constant), TIMS, SIMP, SIDCR
d Dependent Variable: VF

Multiple Linear Regressions (Step-Wise)

Dependent Variable: MF
Independent Variables: SIVCR, SIMP, SIDCR, SCOMP, SREL, TDE, TMSYS, TIMS

Descriptive Statistics

	Mean	Std. Deviation	N
MF	3.9128	.47216	60

Correlations

		MF	SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS
Pearson Correlation	MF	1.000	.506	.530	.299	.429	.297	.331	.326	.393
	SIVCR	.506	1.000	.588	.519	.634	.527	.308	.350	.514
	SIMP	.530	.588	1.000	.659	.462	.386	.413	.543	.368
	SIDCR	.299	.519	.659	1.000	.414	.122	.532	.537	.522
	SCOMP	.429	.634	.462	.414	1.000	.615	.346	.491	.434
	SREL	.297	.527	.386	.122	.615	1.000	.128	.136	.044
	TDE	.331	.308	.413	.532	.346	.128	1.000	.565	.358
	TMSYS	.326	.350	.543	.537	.491	.136	.565	1.000	.580
	TIMS	.393	.514	.368	.522	.434	.044	.358	.580	1.000
Sig. (1-tailed)	VF	.	.000	.000	.010	.000	.011	.005	.005	.001
	SIVCR	.000	.	.000	.000	.000	.000	.008	.003	.000
	SIMP	.000	.000	.	.000	.000	.001	.001	.000	.002
	SIDCR	.010	.000	.000	.	.001	.176	.000	.000	.000
	SCOMP	.000	.000	.000	.001	.	.000	.003	.000	.000
	SREL	.011	.000	.001	.176	.000	.	.164	.151	.369
	TDE	.005	.008	.001	.000	.003	.164	.	.000	.002
	TMSYS	.005	.003	.000	.000	.000	.151	.000	.	.000
	TIMS	.001	.000	.002	.000	.000	.369	.002	.000	.

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	SIMP	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	SIVCR	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: MF

Model Summary(f)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.530(a)	.281	.269	.40373	
2	.582(b)	.339	.316	.39053	1.851

a Predictors: (Constant), SIMP
b Predictors: (Constant), SIMP, SIVCR
c Dependent Variable: MF

ANOVA (f)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.699	1	3.699	22.695	.000(a)
	Residual	9.454	58	.163		
	Total	13.153	59			
2	Regression	4.460	2	2.230	14.621	.000(b)
	Residual	8.693	57	.153		
	Total	13.153	59			

a Predictors: (Constant), SIMP
b Predictors: (Constant), SIMP, SIVCR
c Dependent Variable: MF

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.278	.347		6.565	.000		
	SIMP	.443	.093	.530	4.764	.000	1.000	1.000
2	(Constant)	1.874	.381		4.915	.000		
	SIMP	.297	.111	.356	2.671	.010	.654	1.528
	SIVCR	.251	.112	.297	2.233	.029	.654	1.528

a Dependent Variable: MF

Excluded Variables(f)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	SIVCR	.297(a)	2.233	.029	.284	.654	1.528	.654
	SIDCR	-.089(a)	-.597	.553	-.079	.566	1.767	.566
	SCOMP	.233(a)	1.901	.062	.244	.786	1.272	.786
	SREL	.109(a)	.899	.372	.118	.851	1.175	.851
	TDE	.135(a)	1.108	.273	.145	.829	1.206	.829
	TMSYS	.055(a)	.408	.685	.054	.706	1.417	.706
	TIMS	.229(a)	1.960	.055	.251	.864	1.157	.864
2	SIDCR	-.166(b)	-1.135	.261	-.150	.539	1.854	.483

	SCOMP	.129(b)	.918	.363	.122	.585	1.708	.487
	SREL	.005(b)	.037	.971	.005	.714	1.401	.549
	TDE	.113(b)	.948	.347	.126	.823	1.215	.595
	TMSYS	.041(b)	.320	.750	.043	.704	1.420	.525
	TIMS	.150(b)	1.196	.237	.158	.729	1.372	.552

a Predictors in the Model: (Constant), SIMP
b Predictors in the Model: (Constant), SIMP, SIVCR
c Dependent Variable: MF

Multiple Linear Regressions (Step-Wise)

Dependent Variable: DF
Independent Variables: SIVCR, SIMP, SIDCR, SCOMP, SREL, TDE, TMSYS, TIMS

Descriptive Statistics

	Mean	Std. Deviation	N
DF	3.9128	.47216	60

Correlations

		DF	SIVCR	SIMP	SIDCR	SCOMP	SREL	TDE	TMSYS	TIMS
Pearson Correlation	DF	1.000	.468	.451	.177	.550	.317	.121	.296	.248
	SIVCR	.468	1.000	.588	.519	.634	.527	.308	.350	.514
	SIMP	.451	.588	1.000	.659	.462	.386	.413	.543	.368
	SIDCR	.177	.519	.659	1.000	.414	.122	.532	.537	.522
	SCOMP	.550	.634	.462	.414	1.000	.615	.346	.491	.434
	SREL	.317	.527	.386	.122	.615	1.000	.128	.136	.044
	TDE	.121	.308	.413	.532	.346	.128	1.000	.565	.358
	TMSYS	.296	.350	.543	.537	.491	.136	.565	1.000	.580
	TIMS	.248	.514	.368	.522	.434	.044	.358	.580	1.000
Sig. (1-tailed)	DF	.	.000	.000	.088	.000	.007	.179	.011	.028
	SIVCR	.000	.	.000	.000	.000	.000	.008	.003	.000
	SIMP	.000	.000	.	.000	.000	.001	.001	.000	.002
	SIDCR	.088	.000	.000	.	.001	.176	.000	.000	.000
	SCOMP	.000	.000	.000	.001	.	.000	.003	.000	.000
	SREL	.007	.000	.001	.176	.000	.	.164	.151	.369
	TDE	.179	.008	.001	.000	.003	.164	.	.000	.002
	TMSYS	.011	.003	.000	.000	.000	.151	.000	.	.000
	TIMS	.028	.000	.002	.000	.000	.369	.002	.000	.

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	SCOMP	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	SIMP	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	SIDCR	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: DF

Model Summary(f)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.550(a)	.303	.291	.55200	
2	.593(b)	.352	.329	.53693	1.781
3	.656(c)	.430	.400	.42332	1.875

a Predictors: (Constant), SCOMP
b Predictors: (Constant), SCOMP, SIMP
c Predictors: (Constant), SCOMP, SIMP, SIDCR
d Dependent Variable: DF

ANOVA (f)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.676	1	7.676	25.190	.000(a)
	Residual	17.673	58	.305		
	Total	25.348	59			
2	Regression	8.916	2	4.458	15.463	.000(b)
	Residual	16.433	57	.288		
	Total	25.348	59			
3	Regression	10.200	3	3.400	12.568	.000(c)
	Residual	15.149	56	.271		
	Total	25.348	59			

a Predictors: (Constant), SCOMP
b Predictors: (Constant), SCOMP, SIMP
c Predictors: (Constant), SCOMP, SIMP, SIDCR
d Dependent Variable: DF

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.171	.486		2.408	.019		
	SCOMP	.619	.123	.550	5.019	.000	1.000	1.000
2	(Constant)	.610	.545		1.119	.268		
	SCOMP	.490	.135	.435	3.617	.001	.786	1.272
	SIMP	.289	.140	.249	2.074	.043	.786	1.272
3	(Constant)	.439	.534		.823	.414		
	SCOMP	.537	.133	.477	4.040	.000	.765	1.307
	SIMP	.499	.166	.430	3.007	.004	.523	1.913
	SIDCR	-.240	.110	-.303	-2.179	.034	.551	1.816

a Dependent Variable: DF

Excluded Variables(f)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	SIVCR	.199(a)	1.414	.163	.184	.597	1.674	.597
	SIMP	.249(a)	2.074	.043	.265	.786	1.272	.786
	SIDCR	-.061(a)	-.502	.618	-.066	.829	1.207	.829
	SREL	-.034(a)	-.242	.809	-.032	.622	1.608	.622
	TDE	-.079(a)	-.673	.504	-.089	.880	1.136	.880
	TMSYS	.035(a)	.273	.786	.036	.759	1.317	.759
	TIMS	.011(a)	.092	.927	.012	.812	1.232	.812

2	SIVCR	.093(b)	.606	.547	.081	.487	2.053	.487
	SIDCR	-.303(b)	-2.179	.034	-.280	.551	1.816	.523
	SREL	-.076(b)	-.555	.581	-.074	.609	1.642	.562
	TDE	-.166(b)	-1.405	.166	-.185	.799	1.252	.713
3	TMSYS	-.083(b)	-.615	.541	-.082	.632	1.581	.632
	TIMS	-.042(b)	-.345	.731	-.046	.776	1.289	.706
	SIVCR	.148(c)	.985	.329	.132	.475	2.105	.475
	SREL	-.194(c)	-1.391	.170	-.184	.541	1.847	.471
	TDE	-.087(c)	-.699	.487	-.094	.696	1.437	.480
	TMSYS	-.014(c)	-.100	.921	-.013	.593	1.685	.497
	TIMS	.061(c)	.480	.633	.065	.669	1.495	.475

a Predictors in the Model: (Constant), SCOMP
b Predictors in the Model: (Constant), SCOMP, SIMP
c Predictors in the Model: (Constant), SCOMP, SIMP, SIDCR
d Dependent Variable: DF

APPENDIX – G

AHP WEIGHTS MATRICES

AHP Weights Matrix: Respondent - Researcher

Criteria	Volume Flexibility	Modification Flexibility	Delivery Flexibility	Geometric Mean (GM)	Weights
Volume Flexibility	1	1/3	1/7	0.362	0.081
Modification Flexibility	3	1	1/5	0.843	0.188
Delivery Flexibility	7	5	1	3.271	0.731

Xmax = 3.065; Consistency Index = 0.032; Consistency Ratio = 5.6%

AHP Weights Matrix: Respondent - Sourcing Manager

Criteria	Volume Flexibility	Modification Flexibility	Delivery Flexibility	Geometric Mean (GM)	Weights
Volume Flexibility	1	1	1/3	0.693	0.221
Modification Flexibility	1	1	1	1.000	0.319
Delivery Flexibility	3	1	1	1.442	0.460

Xmax = 3.136; Consistency Index = 0.068; Consistency Ratio = 11.7%

AHP Weights Matrix: Respondent - Technology Manager

Criteria	Volume Flexibility	Modification Flexibility	Delivery Flexibility	Geometric Mean (GM)	Weights
Volume Flexibility	1	1/3	1/5	0.405	0.105
Modification Flexibility	3	1	1/3	1.000	0.258
Delivery Flexibility	5	3	1	2.466	0.637

Xmax = 3.039; Consistency Index = 0.019; Consistency Ratio = 3.3%

APPENDIX – H

POSITION MATRICES

Position Matrix: Respondent - Researcher

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach	Weight
Volume Flexibility	0.9	0.3	0.3	0.9	0.7	0.081
Modification Flexibility	0.5	0.7	0.5	0.7	0.7	0.188
Delivery Flexibility	0.3	0.9	0.7	0.3	0.3	0.731

Position Matrix: Respondent - Sourcing Manager

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach	Weight
Volume Flexibility	0.7	0.3	0.3	0.7	0.7	0.221
Modification Flexibility	0.5	0.5	0.5	0.7	0.5	0.319
Delivery Flexibility	0.3	0.7	0.7	0.3	0.7	0.460

Position Matrix: Respondent - Technology Manager

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach	Weight
Volume Flexibility	0.9	0.3	0.3	0.5	0.9	0.105
Modification Flexibility	0.7	0.7	0.7	0.5	0.5	0.258
Delivery Flexibility	0.3	0.9	0.5	0.3	0.3	0.637

APPENDIX – I

WEIGHTED POSITION MATRICES

Weighted Position Matrix: Respondent - Researcher

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.0729	0.0243	0.0243	0.0729	0.0567
Modification Flexibility	0.0942	0.1319	0.0942	0.1319	0.1319
Delivery Flexibility	0.2192	0.6576	0.5115	0.2192	0.2192

Weighted Position Matrix: Respondent - Sourcing Manager

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.1548	0.0663	0.0663	0.1548	0.1548
Modification Flexibility	0.1595	0.1595	0.1595	0.2232	0.1595
Delivery Flexibility	0.1380	0.3220	0.3220	0.1380	0.3220

Weighted Position Matrix: Respondent - Technology Manager

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.0943	0.0314	0.0314	0.0524	0.0943
Modification Flexibility	0.1808	0.1808	0.1808	0.1291	0.1291
Delivery Flexibility	0.1911	0.5733	0.3185	0.1911	0.1911

APPENDIX – J

HADLEY'S MATRICES OF CAUTIOUS OPTIMISM

Hadley's Matrix - 80% Optimism

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.1384	0.0579	0.0579	0.1343	0.1352
Modification Flexibility	0.1635	0.1710	0.1635	0.2044	0.1534
Delivery Flexibility	0.2030	0.5905	0.4729	0.2030	0.2958

Hadley's Matrix - 60% Optimism

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.1220	0.0495	0.0495	0.1138	0.1155
Modification Flexibility	0.1462	0.1612	0.1462	0.1856	0.1473
Delivery Flexibility	0.1867	0.5233	0.4343	0.1867	0.2696

Hadley's Matrix - 40% Optimism

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.1056	0.0411	0.0411	0.0933	0.0959
Modification Flexibility	0.1288	0.1514	0.1288	0.1668	0.1413
Delivery Flexibility	0.1705	0.4562	0.3957	0.1705	0.2434

Hadley's Matrix - 20% Optimism

Profile ⇨ Objectives ⇩	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Volume Flexibility	0.0892	0.0327	0.0327	0.0728	0.0763
Modification Flexibility	0.1115	0.1417	0.1115	0.1480	0.1352
Delivery Flexibility	0.1542	0.3891	0.3571	0.1542	0.2173

APPENDIX – K

HADLEY'S DOMINANCE MATRICES

Dominance Matrix: Hadley's 80% Optimism

Profile	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Outsourcing based approach	--	2	1	1	1
Strategic Sourcing based approach	1	--	0	2	1
Design Technology based approach	1	2	--	2	1
Manufacturing Technology based approach	1	1	1	--	2
Infrastructural Technology based approach	2	2	2	1	--
Column Sum	5	7	4	6	5
Rank	**III**	**I**	**V**	**II**	**III**

Dominance Matrix: Hadley's 60% Optimism

Profile	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Outsourcing based approach	--	2	1	1	2
Strategic Sourcing based approach	1	--	0	2	1
Design Technology based approach	1	2	--	2	2
Manufacturing Technology based approach	1	1	1	--	2
Infrastructural Technology based approach	1	2	1	1	--
Column Sum	4	7	3	6	7
Rank	**IV**	**I**	**V**	**III**	**I**

Dominance Matrix: Hadley's 40% Optimism

Profile	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Outsourcing based approach	--	2	1	1	2
Strategic Sourcing based approach	1	--	0	2	1
Design Technology based approach	1	2	--	2	2
Manufacturing Technology based approach	1	1	1	--	2
Infrastructural Technology based approach	1	2	1	1	--
Column Sum	4	7	3	6	7
Rank	**IV**	**I**	**V**	**III**	**I**

Dominance Matrix: Hadley's 20% Optimism

Profile	Outsourcing based approach	Strategic Sourcing based approach	Design Technology based approach	Manufacturing Technology based approach	Infrastructural Technology based approach
Outsourcing based approach	--	2	1	1	2
Strategic Sourcing based approach	1	--	0	2	1
Design Technology based approach	1	2	--	2	2
Manufacturing Technology based approach	1	1	1	--	2
Infrastructural Technology based approach	1	2	1	1	--
Column Sum	4	7	3	6	7
Rank	**IV**	**I**	**V**	**III**	**I**