FLEXIBLE MANAGEMENT OF TECHNOLOGY ADOPTION AND ADAPTATION IN MANUFACTURING INDUSTRY

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By

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CERTIFICATE

Certified that the thesis entitled, **'FLEXIBLE MANAGEMENT OF TECHNOLOGY ADOPTION AND ADAPTATION IN MANUFACTURING INDUSTRY'**, being submitted by Amanpreet Singh Sethi, 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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ABBREVIATIONS

A	Average Value
AdeQuaTE	Academy of Quality in Training and Education
AHP	Analytic Hierarchy Process
AIMA	All India Management Association
AMT	Advanced Manufacturing Technologies
APEAL	Automotive Performance, Execution and Layout
AS/RS	Automated Storage And Retrieval System
BHU and IT_BHU	Banaras Hindu University Institution of Technology, Banaras Hindu University
BSII BSIII/ BS3	Bharat Stage Norms (Automobile pollution related)
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CD	Compact Disc
C-EPS	Column type Electronic Power Steering
CFT	Cross-functional team
CI	Consistency index
CII and CII-EXIM	Confederation of Indian Industry Confederation of Indian Industry – Export Import
CMERI	Govt. of India's research institute at Durgapur
CNC's	Computer Numerical Control Machines
CNG	Compressed natural gas
Coeff.	Coefficient
CPV	Concentrator photovoltaic
CR	Consistency ratio

CRM	Customer relationship management
DMU	Digital mock-up
DVD	Digital versatile disc
EBITDA	Earnings before Interest, Taxes, Depreciation and Amortization
ECU	Electronic controller unit
EOU	Export oriented unit
EPAM	Electric power assist module
EPS	Earnings Per Share
ERP	Enterprise Resource Planning
FDI	Foreign direct investment
FEA	Finite elements analysis
FMS	Flexible Manufacturing System
FST	Fuzzy Set Theory
FTC	Firm-level technological capabilities
GCC	Gulf co-operation council
GT	Group Technology
HD	High density
HVPT	High Volume Production Trial
ICT / IT	Information and Communication Technology / Information Technology
IIT	Indian Institute of Technology
IP11:	Role of government in technology adoption
IP12:	Impact of globalization on technology adoption
IP13:	Role of top management in technology adoption
IP14:	Role of Manufacturing strategy and technology adoption policies in technology adoption

IP15:	Role of Human factor in technology adoption
IP21:	Role of Government in technology adaptation
IP22:	Role of top Management in Technology Adaptation
IP23:	Role of Employees' Skill, Education and Attitude
IP24:	Role of In-house R&D in technology adaptation
IP25:	Role of Adaptation Policies in technology adaptation
IPO	Initial public offer
JIT	Just in time
JV	Joint venture
KOEL	Kirloskar Oil Engines Ltd
LCV	Light commercial vehicles
LICs	Low income countries
LPG	Liquefied petroleum gas
M&M	Mahindra and Mahindra
Moserbaer	Moserbaer India Limited
MPI	Multi point injection
MRP	Material Requirement Planning
MSIL	Maruti Suzuki India Limited
MSM	Maruti Service Masters
MUL	Maruti Udyog Limited
MUV	Multi utility vehicle
N2N	Node to node
NICs	Newly Industrialized countries
NMT	New manufacturing technology
ODD	Optical Disk Drive

OEM	Original Equipment Manufacturer
OFM	Option Field Methodology
OPM	Option Profile Methodology
p	Statistic
PAT	Profit after Tax
PDM	Product design management
PLM	Product life management
POM	Production and Management course
PSIDC	Punjab State Indutries Development Corporation
PTL	Punjab Tractors Limited
PV	Photovoltaic
R / r	Correlation coefficient
ROCE,/ RoCE	Return on Capital Employed
ROI	Return on investment
SAP	Situation-Actor-Process
SAP-LAP	Situation - Actor - Process – Learnings - Action - Performance
SCADA	Type of a computer storage which allow two-way information flow
SCS	Success due to adoption and adaptation of new technology
SD	Standard Deviation
Sig.	Significance
SKSSL	Sona Koyo Steering Systems Limited
SMC	Suzuki Motor Company
SME	Small and Medium Enterprise
SPSS	Statistical Package for Social Sciences (Software)
SQA	Supplier Quality Assurance

SWOT	Strength, Weaknesses, Opportunity, Threat
TC	Technological capability
TM	Technology Management
TPMCPM	A capability assessment process model
TPS	Toyota Production System
USB	Universal serial bus
VA	Value Analysis
VE	Value Engineering
VTVV SHED	For testing evaporative emission of vehicles
TPM	Total productive maintenance
TQM	Total quality management

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ABSTRACT

The manufacturing sector throughout the world in general and in India and other less developed countries in particular has undergone major changes in last few decades. The pace of change in India increased when firms adopt and adapt new technologies, particularly since its economy started the process of globalization, privatization and liberalization in early 1990s. Manufacturing industries in the developed world are now going in for customized production than mass production and involving extensive use of new technologies, particularly information and communication technologies (ICTs), for reducing inventory and storage costs. Many of these changes are also visible in Indian industry as well.

A brief overview of enormous literature on technology adoption and adaptation revealed that flexibility issues and links of these to capability building in manufacturing firms have not been adequately addressed. Therefore, specific issues of flexible management of technology adoption and adaptation for capacity building in Indian manufacturing industry in the changed economic environment were identified for examination through research. Broad objective of this research work was to analyze the technology adoption and adaptation processes used in Indian manufacturing companies and to develop a framework representing the linkages of technology adoption and adaptation with capability building of these companies.

Major issues taken up were to assess the technology adoption and adaptation practices and policies, identify problems of and barriers to technology adoption and adaptation, study flexible approaches in technology adoption and adaptation for capability building, and develop a conceptual framework of flexible system for this. Literature was reviewed extensively for identifying specific factors affecting technology adoption and adaptation, and capability building.

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 flexible management of technology adoption and adaptation for developing technological capabilities constitutes the 'process'. A simple, relevant and comprehensive questionnaire pertaining

to the desired conceptual framework has been peculiarly designed, for gathering information on the status of different types of technological capabilities and various practices followed for adoption and adaptation of new technology in the Indian manufacturing industry. The questionnaire has been designed after extensive literature review and validated through peer review from academicians, consultants and practitioners from the industry. A 1–4 Likert-type scale has been employed for all item measures in the questionnaire. Descriptive and empirical analyses of the data collected through the survey have been carried out to assess the status of technology adoption vis-à-vis its adaptation and present level of technological capabilities. Further, the associations between various independent constructs and outputs (technological capabilities, success due to adoption and adaptation of new technology and flexibility) have been established using canonical correlation and multiple regression analysis.

The association of technology adoption and adaptation policies with capability building has been established using correlation coefficient. Various problems that are faced when existing and new technology are brought into contact are also explored through the survey. Further this research work identified critical barriers in technology adoption and adaptation and suggested action required overcoming these barriers.

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, Gurgaon; Sona Koyo Steering Systems Limited, Gurgaon; Moserbaer India Limited, Noida; and Punjab Tractors Limited , 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. The analyzed result of the case studies depicts the total industrial scenario about the present level of technological capabilities.

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 adoption and adaptation practices have been developed and include: hard technology adoption approach, soft technology adoption approach, technology adaptation approach, and system adaptation approach.

A conceptual framework has been developed representing the linkages between technology adoption and adaptation and technological capability building of a company. The order of implementing various strategies for building the different technological capabilities in Indian context has been recommended through another framework developed in this research work.

A summary of the research work described above was prepared showing its findings, results, conclusions, and the recommendations. This research concludes that manufacturing companies must concentrate on the technology adaptations, followed by system adaptations, and then on hard technology adoptions for building their overall technological capabilities. The thesis concludes with suggestions for further research.

CHAPTER - I

INTRODUCTION

1.1 TECHNOLOGICAL CHANGE

Change and development are integral to any field, and management of technology is no exception to this. Technology and its management have gained importance ubiquitously in post industrial era. Transfer of technology from one company to another and from one country to other helps in advancement of industry to a great extent. Technological progress is the engine of economic growth. During the updating progress of the technologies, new technologies drive out old technologies, because they help reduce costs and increase revenues. New technologies also improve output quality, enrich product variety, shorten production process or expand production capacity. Every technology has its own life span and it exits from the market when it no longer satisfies the customers' demands, accommodates desired flexibility, economizes resources, or protects the environment (Jain and Srivastava, 1989).

The survival of manufacturing industry depends upon effective transfer of technology from outside sources. Implementation process for new technology includes needs assessment, selection, negotiation, acquisition, adoption and adaptation of technology. For gaining competitive advantage and developing firm's internal capabilities, technology adoption and adaptation are considered to be among the critical activities for a firm. Therefore, linkages between technology adoption and adaptation, and capability building are very important for developing competitive advantage for Indian industry.

There is a lack of any organized attempt to understand how these activities are being carried out in Indian industry. This research is intended to understand the complexities involved in technology adoption and adaptation activities at firm level, and their linkages with technological capability building in manufacturing industry; and to develop a flexible system framework to carry out these activities effectively.

1.2 FLEXIBILITY

Flexibility is the ability of a system to react to and accommodate changes. To be flexible, the flexibility must exist during the entire life cycle of a product, from design to manufacturing to distribution. Various researchers have defined flexibility in their own way. Mandelbaum (1978) defined flexibility as the ability to respond effectively to changing circumstances.

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 the 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. This attribute is reflected in concepts such as robustness or resilience. Robustness characterizes the capability to absorb shocks and withstand perturbation whereas resilience refers to the ability to come back from the brink of disaster without bearing permanent scars or disabilities (Bahrami, 1992).

Also, flexibility is the ability to change or react with little penalty in time, effort, cost or performance (Upton, 1994). He has presented a framework for analysis of manufacturing flexibility, and applied it to three business situations to clearly define the type of flexibility of concern in each case.

A flexible system is one that is able to respond to change, and flexibility is the ability of the system to respond effectively to change. The changing circumstances include both internal and external changes. The ability to cope with the internal changes require a degree of redundancy in the system, whereas the ability to cope with the external changes require that the system be versatile and capable of producing wide variety of part types with minimal changeover times and costs to switch from one product to another (Buzacott, 1982).

Flexibility is the ability of a system to adopt a range of states. In addition, flexibility also depends on the ease with which it can move from one state to another. A system which moves from one state to another, smoothly and economically, should be considered more flexible than a system that achieves the same change at a greater cost or organizational disruption. (Slack, 1983).

1.3 TECHNOLOGY ADOPTION

Simply put, adoption, the first stage of the technology transfer process, is a firm's awareness of a certain technology's existence and the firm's initial pursuit of that technology. Adoption decision refers to the processes by which any new 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.

Firms adopt a new technology when they believe that adoption will have a short or long term payoff in higher profits. Another major strategic reason can be their interest in gaining experience with the new technology for building technological capabilities. Thus adoption of strategic technologies that enhance the competitiveness of the firm has emerged as one of the most important responsibilities of manufacturing managers. These firms, which are able to adopt a particular type of manufacturing technology, become quite comfortable in adopting its next level.

Technological progress cannot be stopped, the new technological developments have and will attract criticism, and the introduction of intelligent technologies may be helpful to mitigate the adverse effects, such as, job losses, environmental pollution, and high rate of accidents. Communication regarding advantages of new technology by opinion leaders can prove to be helpful in overcoming criticism to new technology adoption.

1.4 TECHNOLOGY ADAPTATION

Adaptation means to carry out technological design and redesign of the acquired technology for making it suitable for local conditions. At this level of rooting, a firm is capable of going beyond mere imitation and is able to customize the technology to fulfill needs that it was not originally intended to serve. This requires a keen understanding of the development theory underlying the technology and its interdependencies with other technologies. This comprehension enhances the adaptability and competitiveness of the firm in a changing environment. The adaptation is commonly aimed at making the adopted processes and products more effective in local environment. Transferred technology cannot be said to be fully absorbed, until the technology has been made indigenous and regenerative, through complete digestion and absorption. Little can be expected from new – including imported – technology without the capability to modify and improve it for domestic applications. The development of a new improved technology is possible only after such modifications are carried out in acquired technology. In-house R&D is an important prerequisite for the sound selection, efficient assimilation, and fruitful adaptation of new technologies. The technology selection should explicitly consider the technology content in order to facilitate appropriate technology adaptation in a firm.

1.5 TECHNOLOGICAL CAPABILITIES

Technological capability represents the ability of a productive enterprise to handle industrial technologies and cope with technological change. Broadly, they can be referred to as those abilities of an organization, which enable it to undertake various technological activities. Building, improving and sustaining firm-level technological capabilities have become particularly crucial for less developed countries, consequent to their joining the open world economy. Such efforts have important implications to the success of their firms in this era of fierce competition. The development of technological capabilities takes place through internal and external routes. The external route is through transfer of technology.

Research on technological capabilities can be classified into two conceptual dimensions, at micro level and at macro level; both for developed as well as less developed countries. The research agenda in respect of less developed countries shifted from topics such as factor pricing, technology choice, and technology transfer to the real technological change taking place in them. While developed countries move from research to development, and then to engineering, less developed countries largely progress in the reverse direction. Developed countries are largely engaged in risk, skill, effort, and time intensive activities such as new product, process or application development. Technological activities in less developed countries, such as adaptation of acquired technologies to local requirements and making minor improvements, are relatively far less intensive in terms of the above-mentioned criteria. Even measures or indicators of technological capabilities found in studies on developed countries are not appropriate in the context of less developed countries. Besides, capability studies in the context of developed countries have largely focused on "innovating capability" which constitutes only one of the five elements of technological capabilities for less developed countries. In fact, measures in the case of less developed countries should be for the whole range of firm level technological capabilities and not just one aspect of it.

1.5.1 Classification of technological capabilities:

Technological capabilities have been categorized in following five categories (Paul, 2004).

- Acquiring Capabilities
- Transforming Capabilities
- Modifying Capabilities
- Vending Capabilities
- Innovating Capabilities

Each of these capabilities has to be individually developed by the companies for building overall technological capabilities.

Acquiring capability

It refers to acquisition of technology components and other related resources. This may include capability of a firm to:

- justify and specify clearly the technologies to be bought based on detailed engineering studies and translation of basic process parameters into layout, plant and equipment;
- identify suitable sellers of technology and carry out sound technology, strategic and resource fit assessments;
- identify the most suitable mechanism(s) for buying technology;
- negotiate effective terms for the transaction of the technology;
- identify funding sources and obtain funds at competitive rates for expansion and growth;
- effectively access necessary material inputs for production; and
- undertake project planning and execution.

Development of acquiring capabilities result in greater vitality of the enterprise in undertaking technological change management.

Transforming capability

It refers to effective utilization of available technologies for transformation of raw materials into finished goods. This may include capability of a firm to:

- effectively utilize available plant and equipment

- plan and control production operations
- carry out troubleshooting and good predictive, preventive and emergency (breakdown) maintenance
- quickly change over to new models
- use computerized information and control systems to provide information support and networking for production operations

Development of transforming capabilities means gradual progress towards optimal use of installed technology components and mobilization of all resources for optimum benefits.

Modifying capability

It refers to continuous improvement of all activities and technology components. This may include capability of a firm to:

- duplicate acquired machinery and equipment parts requiring replacement;
- adapt system and technology mutually for better efficiency;
- carry out minor, incremental improvement for superior quality outputs;
- implement human resources development programs for all activities;
- introduce advanced mgt techniques for effective performance; and
- prepare production system expansion programmes and implementing it properly.

Development of modifying capabilities increase augmentation in mobilizing resources through cost minimization and customer value maximization

Vending capability

It refers to distributing, selling and servicing of outputs using technology. This may include capability of a firm to:

- sell outputs for optimum use of resources and production capacity;
- monitor external situation and evaluating performance;
- identify new markets and promote sales of new products in new markets; and
- provide after-sales services to enhance perceived customer satisfaction.

Development of the vending capability may be seen in the increase in the market segments and increase in market shares of those segments

Innovating capability

It refers to utilization of process development technologies. This may include capability of firm to:

- reverse engineer acquired technology;
- carry out product innovations;
- carry out process innovations;
- introduce application innovations;
- introduce system innovations; and
- introduce core competence leveraging innovations.

Development of innovating capabilities indicate realization of crucial self-reliance and control in the supply of critical technology components for effective international market competition in the face of rapid technological changes.

1.6 FLEXIBLE SYSTEMS METHODOLOGY

Flexibility is the ability to respond effectively to the ever-changing and increasing demands of the customer. For these demands to be satisfied, flexibility should be built into the total system consisting of various 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 the desired. High speed and accuracy combined with flexibility and optimized throughput, are the goals expected from next level of technology.

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. The concept of flexibility can provide a solution to the paradox. This concept 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 so as 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) discussed this paradigm and concluded that this methodology was more realistic and by using this, more creativity will be applied to the problem solving.

This research has employed flexible system methodology to develop a conceptual framework representing linkages between technology adoption and adaptation; and technological capabilities of these manufacturing industries.

1.7 OBJECTIVES

The objective of this research work is to analyze the technology adoption and adaptation processes used in manufacturing industry; and to develop a framework representing the linkages of technology adoption and adaptation with capability building of these companies.

1.7.1 Issues

The following issues were taken up during this research work:

1. Present status of imported technology adoption and adaptation practices being carried out in manufacturing industry.
2. Conceptualization, generation, refinement, and structuring of ideas regarding flexibility in technology management with reference to adoption and adaptation of technology, and capability building.
3. Development of a conceptual framework of flexible system for technology adoption and adaptation and capability building.
4. Refinement, modification, and validation of the developed framework.
5. Presence and absence of technology adoption and adaptation policies and its impact on capability building.
6. Problems that occur when existing and new technology are brought into contact.
7. Identification of critical barriers in technology adoption and adaptation and action required overcoming these barriers.
8. Types of flexibility available in technology adoption and adaptation and capability building.

1.8 SCOPE

This work is limited to those medium and large scale manufacturing enterprises in north India, which are in process of acquiring, developing or utilizing the new technology. The main focus has been on organizational, managerial and employees' issues related to flexible management of technology adoption and adaptation.

This work started with addressing issues related to imported technology adoption and adaptation, however during the course of study and field work it was found, particularly in discussion with senior managers that most of the companies also largely relied on new technology that is not necessarily imported. Therefore, after pre-testing stage of the questionnaire, new technology has been used as a broad-based term instead of imported technology in this research work.

1.9 ORGANIZATION OF THE THESIS

The write up of the thesis is divided into seven chapters: i. Introduction, ii. Literature Review, iii. Design of the Study, iv. Survey on Flexible Management of Technology Adoption and Adaptation, v. Case Studies on Flexible Management of Technology Adoption and Adaptation, vi. Development of Implementation Plan for Technological Capability Building, and vii. Conclusions and Recommendations.

Introduction to the subject of technological capabilities, technology adoption and adaptation are covered in Chapter – I. The need of technological capabilities and objectives and issues connected with the design of such a system are briefly discussed. Further, the scope of study, flexible systems methodology, in brief, and scheme of whole study is covered.

Extensive literature review of the subject involving technological capabilities, technology adoption and adaptation and other closely related areas have been presented in Chapter – II. The literature has also been reviewed on methodologies to be used in carrying out the research.

Chapter – III describes in detail the overall design of study, which includes phases of research and the methodology adopted for carrying out this research work. Details of work done in each phase, tools, techniques and models used in the dissertation are also presented in this chapter. The research has been carried out using flexible system methodology. The problem has been conceptualized as a SAP (Situation-Actor-Process) paradigm. In this framework, the 'situation' aspect comprises of the present industrial situation in manufacturing industry, whereas the organization constitutes the 'actor' aspects. Managing the new technology adoption and adaptation flexibly and its role in building the technological capabilities constitute the 'process'.

In Chapter IV, the results of detailed survey conducted in various manufacturing enterprises in the north India have been presented, analyzed and discussed in detail. Survey was based on a questionnaire containing around 180 simple and multiple choice questions pertaining to the desired conceptual framework. Special emphasis has been given to seek information related to the current level of technological capabilities of the organization. The suggestions of peers, senior executives from the industries and academics have been incorporated to make the questionnaire relevant to the purpose so that it may bring out key outcomes. The descriptive analysis for the research parameters have been carried out to assess their present status in the manufacturing industries.

While analyzing data, independent and dependent variables (constructs) have been formulated on the basis of literature review and the issues of this research. Five factors affecting technology adoption and technology adaptation each, have been identified as independent variables. Present status of technological capabilities, success due to implementation of technology adoption and adaptation, and flexibility, have been taken as dependent variables. The convergent and discriminant validities of the constructs and their measures have been carried out. Various statistical tools and techniques have been employed using SPSS software to get 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 used as the appropriate multivariate statistical technique for this purpose. As a precursor to canonical correlation analysis, 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, multiple regression analyses were carried out using stepwise method. Various types of flexibilities in technology adoption and adaptation and technological capabilities have been identified. The various barriers to new technology adoption and adaptation alongwith the problems that occur when old and new technologies are brought into contact have also been analyzed using descriptive analyses. The actions for overcoming these barriers and problems have been suggested.

Chapter – V describes in detail four case studies carried out in various manufacturing organizations, which are actors in the context of SAP. The objective of conducting case studies was to look deep into and critically analyze various facets of working of the organizations, including the need of building technological capabilities and the process of technology adoption and adaptation followed therein. These case studies have been analyzed and their results have depicted the industrial scenario about the research objective. Survey results have been validated by these case studies.

In Chapter - VI, the learning issues from survey and case studies have been synthesized and utilized in the domain of a qualitative model to develop and select a suitable plan for building technological capabilities. 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 approaches or courses of actions, to build technological capabilities have been identified as:

1. Hard technology adoption approach
2. Soft technology adoption approach
3. Technology adaptation approach
4. System adaptation approach

Various technological capabilities of the organizations as revealed by the literature were utilized in the qualitative model. The weightages of these capabilities have been worked out by experts using AHP. Further the experts' opinion has been taken to assess the contribution of each profile towards each objective using FST. Utilizing the weightages of the objectives and the contribution of each profile towards each objective and subsequently making dominance matrices, preferred strategies for building technological capabilities under various situations of optimism, pessimism and realism has been selected. Preferred strategies under a cautious optimism approach have also been evolved. Finally, a conceptual framework on "Approaches to Technological Capability Building" has been developed, presented and discussed.

Chapter – VII covers the summary of the research work, its results, conclusions, and the recommendations. Further, the results of the survey and the case studies, and 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 also given in this chapter.

1.10 CONCLUDING REMARKS

While every attempt has been made to make this study as exhaustive, intensive and broad-based as possible, it is appropriate to add here that covering the manufacturing industries in all parts of a country of the size of India, is a stupendous task. All manufacturing industries cannot be covered in an individual led research. This study has been limited to the manufacturing industries of north India only. 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 role of technology adoption and adaptation in building technological capabilities. 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, particularly in area of application research such as technology, 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 (new) technology adoption, adaptation and technological capability building in production industry worldwide from flexible management point of view.

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

- Technology
- Technology management
- Flexibility
- Technology adoption
- Technology adaptation
- Technological capability building

2.2 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) defined technology as the totality of means employed to provide objects necessary for human sustainability and comfort. Zhao and Reisman (1992) stated that the concept of technology can be defined with respect to a context and provides a definition of technology with reference to economics, sociology, anthropology, management etc. 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) provided a similar definition and stated 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 was offered by Gibson (1976) when he stated, "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 is 'technology means the systematic application of scientific or other organized knowledge to practical task.' Broadly speaking, 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 comes with mixed blessings. It considerably enhances human muscular and mental capabilities, and conditions our living surroundings to make it more and more comfortable. The role of technology has been the most crucial in the overall growth and development of a country (Sharif, 1989).

Technology crosses borders in the form of scientific papers, foreign sponsorship of university research, international licensing, cross-border equity stakes in hi-tech start-ups, and international academic conferences. Tapping into the global market for technology is a potentially important source of resource leverage (Hamel and Prahalad, 1993). To go global, a firm has to be strong in technology and market locally. Technology and markets are made global by customer needs. According to Ohmae (1989) globalization is required because customer needs have been globalized and fixed cost of meeting such needs have soared high.

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 (Werther *et al*. 1994).

2.2.1 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 and Glinow, 1990). The shrinking technology life cycles 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. The interdependence of individuals in research and development has been very well appreciated. The authors have discussed the various environmental factors and their effects on the organizational restructuring with special reference to organizations as learning systems, the use of flexible and temporary designs, integration, permeable boundaries, differentiation, and ongoing resolution of competing tensions. Effective high technology organizations are able to deal with many conflicting demands using the appropriate measure (s) proposed. 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.

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). He 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' innovation in products and processes, and adapting designs and processes to shifts in supply and prices input. The top management is considered very important and responsible for R&D improvement and a broad framework has been provided for performance evaluation of R&D programs. Sushil (1990) has presented a concept of `wastivity' which can be made use of in evaluating the R&D performance particularly in minimizing the waste.

The need for creative research for Japan to sustain its global leadership in hi-tech products, has been emphasized by Jun'ichi (1987). After the World War II when Japan needed to establish itself in the world market, started manufacturing inexpensive high-quality goods which helped it in spreading the benefits of modern science and technology around the world. Most of these products were based on the researches conducted in the technologically advanced countries. Japanese manufacturers responded to oil crisis of 1970s very intelligently by automating production to reduce labor cost and offsetting higher fuel bills. The other alternative could be to reduce the head counts which could lead to higher unemployment and de-industrialization of Japan. He also discussed the number of technological breakthroughs realized and commercialized in Japan. A wide gap in the two, shows Japan's weakness in creative research and to overcome this, the author has strongly pleaded the candidature of Japanese universities as a breeding ground for basic researches and inspired researchers.

2.2.2 Impact of new technology

New technology can have different levels of impact depending on their pervasiveness and the structure of organization and society (Rao, 1994). Technology and social change are inter-dependent. The steam locomotive and industrial revolution brought about significant changes in life style and working pattern. Likewise informatization and knowledge intensification in the high tech era are bringing forth some fundamental shifts in values. For example, in agricultural society the wealth used to be decided by agricultural production, while production of agricultural products continued to be a necessity in the industrial age, their abundance is not necessarily a symbol of wealth (Subramanian, 1990).

Choi (1993) has suggested that science and technology are not just one aspect of growth, but a vital factor in socio-economic development particularly among less developed countries. It is this technological revolution that less developed countries would need to harness as an instrument of growth and socio-economic development.

In recent years, in recognition of the pivotal role of new technology in the development process, increasing attention has been directed to the formulation and implementation of technology policies in less developed countries.

Preamble to the National Technology Policy for America 1992, stated that America's economic performance and international (business) influence rest in large part, on its technology base. New technology has accounted for the bulk of US productivity gains during past, spawned entire new industries, created millions of jobs. It has been a primary source of America's ability to get business and maintain a high standard of living for its citizens.

Transfer of technology is important for competition if it significantly improves a firm's competitive advantage or industry structure. Competitiveness has been considered the key issue to economic success and future prosperity in this new globalized economic reality (Barbosa, 1997).

Government can play a vital role in the process of technology transfer. Governments must make money available for research and development and support the local investors who participate in the process of technology transfer. The government regulations need to be conducive on transfer of technology. From active support in the form of subsidies, tax benefits and more indirect methods, government regulations have a significant influence on the economic benefits of technological transformation.

2.3 TECHNOLOGY MANAGEMENT

Twenty-first century is going to be totally dominated by technology and technological competitiveness. The entire world will agree to the fact that the atmosphere for creative application of technology is critical to the economic growth, national security, and social stability (Ramo, 1989).

Technology and its management cannot be narrowly viewed merely in terms of machines, equipment, instruments and processes. Manufacturing technology comprises five interconnected and interdependent facets. Each of these facets need to be recognized explicitly both individually and in terms of its multilateral linkages with others, for the purpose of managing technology effectively. These facets are:

(i) *Production Processes:* This facet includes design and layout of production facilities; type and mix of machines and equipment; flow of information, materials and people;

elements of automation, computer systems and hardware, monitoring, control, maintenance and simulation of operations and facilities.

(ii) *Product and Process Design*: This facet is related with the design of products including materials, parts, components and features, on one hand, and design of processes and their interconnection with products, on the other. Both products and processes may be designed simultaneously in terms of concurrent engineering towards achieving zero defect production.

(iii) *Information Systems*: This facet includes methods and systems for communication, integration, intelligence, production control and overall coordination.

(iv) *Orgaware Technology*: This facet relates to organizational support system that facilitates the transformation process, including administration, communication, integration, coordination, learning, acquisition and retention of knowledge and information and incentive/reward system.

(v) *Material Technology*: This facet relates to the knowledge and use of the properties and attributes of core materials, inter connection of parts, composites and functions.

Production/manufacturing technology, in the holistic sense, describes the way in which the foregoing five facets interact together to convert resources into outputs. Effective management of technology implies continuous improvement, consistency and coordination of all the foregoing five facets. The emphasis is on bringing about continuing and combined improvements in order to sustain and upgrade the company's distinctive competency towards its potential competitive advantage.

Bahouth (1994) has discussed the necessity of exposing future managers to technology management, and identified areas of technology management these future managers should be exposed to. He argued that technology is the major factor behind productivity improvement and the rising standard of living. For some organizations, setting policies regarding the technologies which have an impact on their operations is the same as developing their strategies. Universities are supposed to be the training fields where managers are prepared for future business battles. A few universities, realizing the impact of technology on profitability, have offered business courses in technology management. The increasing importance of technology management in the modern age was discussed by Cyret and Kumar (1994). They discussed the possible applications and problems that can be encountered in its industrial applications.

Orr and Sohal (1999), in their study based on interviews conducted with four German multinationals, have discussed issues of technology management in the context of global manufacturing. Based on observations, they have identified three common strategies/practices adopted by the companies studied namely: maintaining focus on core competencies/technological capabilities; maintaining a continuing dialogue between the R&D function at the headquarters and the overseas operating units; and providing extensive duration and training for all employees. Amin (2000) found that from a viewpoint of strategic research and development, there are many scientific and technological challenges posed by the lack of a unified mathematical framework. Genus and Kaplani (2002) have addressed the synergy between operations, technology management and human resource management by way of a study of operational innovation in firms.

Husain *et al.* (2002) have conducted a study to analyze technology management practices of firms in the automobile industry in India. The situation-actor-process-learning-action-performance (SAP-LAP) paradigm was used to analyze the cases.

Riccaboni and Pammolli (2003) have analyzed the relationships between technological regimes, regimes of local interaction, and the global structure of an industrial network**.** Bhardwaj and Sharma (2005) have conducted a filed study, and reviewed the relevant literature and synthesized issues concerning technology acquisition and technology transfer, as applicable to the automotive industry in particular.

Davies and Ko (2006) have studied and tested the hypothesis that companies, who move away from the traditional Hong Kong business model by adopting up-grading strategies, enjoy superior performance. The broader implication was that Hong Kong manufacturing firms began to escape the iron fetters of a business model originally imposed on them. Mora-Monge *et al.* (2007) have investigated the issue of strategic fit between Advanced Manufacturing Technolgies (AMT) and its impact on performance in less developed countries. Narain *et al*. (2007) reviewed a wide range on literature on the justification of AMT. Bosco (2007) has presented a technology picture of the Lombardy region of France and the main policy actions undertaken in recent years in that region to promote a nest of linkages within actors, moving along the approach of regional innovation system. The evolution of Lombardy's economic structure and international position led the regional government to build up a network of public and private stakeholders in the effort of promoting the creation of new knowledge and supporting innovation at local level.

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 process.

2.3.1 Technology management - operational issues

Management of technology as seen by Asian managers and scientific and educational professionals involves new approaches to developing and managing the human resources, team development and profit sharing while European and other believe in development of an organization structure to handle the issues of coordination, conflicts and collective decision-making alongwith human resource development (Swierczek, 1991).

Change in basic conception of managerial responsibilities is required for improving international competitiveness of technology based firms. The emphasis on narrow specialization of managers within each major functional area delivered results only in restricted domain. Effective integration of specialized functions at successively higher corporate levels, as demonstrated by Japanese in last two decades, is a worth following strategy to improve competitiveness in global market. Making technological contribution to the competitiveness visible, requires reaching beyond R&D and engineering criteria and needs to take internal and external environmental factors into consideration (Gold, 1992).

The CEO's interest in technology management is of paramount importance in bringing a change in the attitude towards the management of technology function (Mathis, 1992). The role of technology managers differs from that of the R&D managers. An R&D manager uses the firm's internal resources to develop technologies that a firm needs to achieve its corporate objectives while the technology manager sees to it that the firm has the technology available to it and uses effectively in all spheres of application. The technology manager forecasts, plans, acquires, develops, and assesses the technology which the firm is using and even takes decisions related to phasing out the same (Mathis, 1992).

The transition to a radically new technology can have a significant and possibly disruptive effect on the work force. Process documentation acts as a basis for internal capability development. Staffing choices concerning the acquisition of capabilities have been explored by Chmelewski and Bilger (1998). The understanding of the need for change in the attitude has to be supplemented with technological forecasting and strategic planning to expedite the change.

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.

A framework has been developed by Bowonder and Miyake (2000) for analyzing technology management issues by combining the knowledge management concepts and ecosystem theory concepts. According to them, technology strategy can be conceptualized as a process of aligning knowledge search, knowledge envisioning, knowledge creation and knowledge evolution with a view to meeting changing customer needs, competitive threats and the future technology trajectory. Da Silveira (2002) has discussed the concept, process and content issues with regard to improvements in operations and technology management (TM). He introduced a framework for the analysis of improvement trajectories (ITs) in operations and TM, by defining the concept of ITs, grounding on the evolutionary economic issues of path dependence and dynamic capabilities. He reviewed and integrated seven dimensions of the process and content of ITs into a research framework. He further build research propositions to base further research and finally, discussed the roles of implementation history, innovation capabilities, and strategic orientation as determinants of IT success.

A few critical success factors in technology management have been pointed out by Metzemaekers (2000). These are: intuition, team-searching and building for a lean and mean supply chain, and the logistic technology that spots the right component suppliers in good time and organizes the system creation process reliably, fast and cost effectively.

An integrative framework covering knowledge enhancement, facilitation and training has been adopted by Government of India to derive benefits both in the short as well as in the long term. Wide-ranging activities have been undertaken in close inter-action with industry, research organizations, technical/management institutes, consultants and others (Kumar and Bhat, 2000).

The growing implications of technological change on society and the dependencies of private and public interests call for a holistic approach to technology management. Based on a systems approach, Tschirky *et al.* (2000) has developed a framework which helps analyze and contrast technology management on a company and national level. The overall process of technology management has been divided into different phases by the different researchers and accordingly the related issues have been addressed. These phases are, forecasting and planning, development/acquisition, transfer, adoption and adaptation, diffusion and substitution, utilization, and phasing out.

Gupta (2001) has used a moderated, regression model and data in his study from a few manufacturing industries to examine the advanced manufacturing strategy based on organizational size. He concluded that high technology has a negative effect on to the size of an organization. This study also revealed that, contrary to some previous research, large and small firms respond differently to technological changes.

Gomes (2004) has distinguished between two concepts of technology: a theoretical level of technology (that is, a technology possibilities frontier) and a level of technology in practice (that is, ready to use in production technology). Having these two concepts in mind, he developed an inter-temporal optimization model in which it may be possible to control the theoretical knowledge frontier The result was an endogenous growth model where long run growth depended on the technology choices made by a social planner.

Based on a quantitative survey in combination with case studies of two Chinese chemical enterprises, Cheng and Bennett's (2007) study concluded that in this industry, building competences is more effective than privatization and restructuring to improve performance. The chemical industry in China is facing fierce competition and exposure to market forces as a result of changes in the country's economic policy. The Chinese government has applied administrative actions rather than simply relying on market forces to address the changing dynamics. It has attempted to privatize state-owned chemical enterprises by corporatization, coupled with industrial restructuring by merging individual state-owned enterprises into groups.

2.3.2 Need of technology transfer

Transfer of technology from developed countries to less developed countries is a mutual necessity (Habibie, 1990). Unfortunately, this perception is not held widely across the globe. The low-income population of the world can become the technology leaders and donors of technology only if income and purchasing power rise. This is likely to happen only with the real increase of productivity of the facilities and quality of their produce. Dependence on natural resources also cannot take a country far ahead, and this has been proved in case of Japan and Korea. The interest of the developed countries, of course, lies in expanding markets for their products.

Technology gap is a reality everywhere. The technology transfer, therefore, becomes imperative in order to bridge the gap. The process of technology diffusion is not transferring shelf knowledge from affluent to poor economies. Perhaps dispatching technologies to third world countries is an act of sale rather than one of technology transfer. Evidently, the international market of technology is an imperfect one as buyers are not adequately informed about the product and they are easily influenced by the potential seller (Banerjee, 1990). Saji *et al.* (2005) have identified the various levels and directions of transferor transferee relationship, and the relationship variables that would determine such a relationship for effective technology transfer in the context of international joint ventures. Nations like Japan and Korea and other newly industrialized countries have decided not to continue re-inventing the wheel by indigenous development of technologies as a means of ensuring improved standards of living. The only solution was to replace so called self reliance and self development by technology transfer through cooperation, and enabling training of young and brilliant scientists and engineers abroad, employment of foreign experts and technicians, and vigorous transfer of appropriate and proven technologies for their adaptation, absorption and eventually further development.

A framework for technology transfer from developed countries to less developed and least developed ones has been proposed by Madu (1989). He has covered a wide variety of topics including relevant technology for a country, the nature of technology, evaluation of indigenous technologies and process of technology transfer.

2.4 CONCEPT OF FLEXIBILITY

Managers recognize and accept that the flexibility is used in two senses; range and response. Differentiating between range and response flexibility helps them to articulate their flexibility needs. They do understand that the response flexibility is more important than range flexibility. They see flexibility as a means to other end and not as an end in itself. The variety and dimensions of flexibility, which mostly concern them are determined by variety and uncertainty (Slack, 1986).

Achieving benefits of flexibility in practice depend on successfully resolving a number of issues, like technical, economic, and organizational. A number of measures which the company must adapt while incorporating flexibility, have been suggested by Bessant and Heywood (1986).

The range of flexibility with concepts of sensitivity and stability has also been characterized. Sensitivity refers to the degree of change tolerated before a deterioration in performance takes place. Stability relates to the size of each disturbance for which it can meet the performance levels expected of it. In other words, while sensitivity determines whether or not a response is needed, stability determines whether or not a system is capable of responding, given that a response is needed. In addition, stability also determines the range of magnitude of changes within which the feasible responses occur. In general, reduced sensitivity and greater stability imply increased flexibility (Gupta and Buzzacott,1989).

Flexibility can be used for both offensive and defensive strategic purposes. An offensive strategic user is proactive in that he/she uses flexibility to continually change his/her environment whereas a defensive strategic user is reactive in that he/she attempts to react to such changes (Swamidass, 1987).

2.4.1 Measuring flexibility

The value of flexibility is the difference between expected profits achieved through a flexible and inflexible system. When the value of flexibility is high for a firm, it implies that firm’s flexibility is low as compared with the levels suitable for the environment that the firm operates in. On the other hand, if the value of the flexibility is low, the flexibility of the firm is judged to be high in relation to its needs. The value of flexibility depends on such factors as the relative frequency of occurrence of different changes that the system is required to cope with, the utility of reduced impact of changes, and the physical properties of the system. Hence, the value of flexibility for the same system may vary depending on the frequency, the type and importance of changes the flexible system is required to cope with (Gupta and Buzacott,1989).

Total system flexibility measure is the weighted combination of two factors; the quickness of response to change, and the economical response to a change factor. However, such measurements can serve, at best, only as conceptual construct for showing nature and importance of both factors (Chung and Chen, 1990).

The manufacturing system flexibility can be measured by two factors; the speed at which there is a response to change, and the economical impact of the response to change. Quickness, being an attribute, can be evaluated as the lead time between a customer’s order receipt and the completion of the product. For a quick response to change, the lead times must be minimised (Masuyama,1983). Two measures of flexibility, application flexibility and adaptation flexibility have been suggested by Zelenovic (1982). He has defined application flexibility as the value of design adequacy. Design adequacy is the probability that the given structure of a production system will adapt itself to environmental conditions and to the process requirements, within the limits of the given design parameters. Adaptations flexibility is defined as the amount of time needed for the system to adapt to a changed situation.

Various flexibility measures have been catagorized into six type of approaches; economic consequence based approach, performance based approach, multi-dimensional approach, petri-net approach, information theoretic approach, and decision theoretic approach (Gupta and Goyal, 1989). Inter-relationships between different types of flexibility has been explored by Rao and Mohanty (1991). They provide a hierarchical approach to the concept of flexibility for assessing the broad flexibility needs of the organization. For this, flexibility have been classified as strategic, tactical, and operational. They also have suggested a framework for measuring flexibility.

Factor analysis has been applied by Dixon (1992) to measure three dimensions of flexibility namely mix flexibility, new product flexibility and modification flexibility. To assess mix flexibility, information has been sought on average number of different product characteristics manufactured during a month, and average number of change-over between these characteristics. To assess new product flexibility, he has collected data on number of samples manufactured and number of new products introduced. For assessing modification flexibility, information has been collected on various aspects related to product that were changed to satisfy customer needs.

2.4.2 Systemic flexibility

The concept of systemic flexibility has been presented by Sushil (1994). 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 the 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.

2.4.3 Technology flexibility

Technology flexibility is the technology characteristic that allows or enables adjustments and other changes to the business process. Technology flexibility has two dimensions, structural and process flexibility, encompassing both the actual technology application and the people and processes that support it. The flexibility of technology that supports business processes can greatly influence the organization's capacity for change. Existing technology can present opportunities for or barriers to business process flexibility through structural characteristics such as language, platform, and design. Technology can also indirectly affect flexibility through the relationship between the technology maintenance organization and the business process owners, change request processing, and other response characteristics. These indirect effects reflect a more organizational perspective of flexibility. The question of 'technology flexibility' has been addressed by developing and validating a measurement model of technology flexibility. Constructs and definitions of technology flexibility were developed by examining the concept of flexibility in other disciplines, and the demands imposed on technology by business processes. The purpose of building a measurement model was to show validity for the constructs of technology flexibility. The paper has discussed the theory of technology flexibility, developed constructs and determinants of this phenomenon, and proposed a methodology for the validation and study of the flexibility of emerging technologies (Nelson *et al.*, 1997).

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.

2.5 TECHNOLOGY ADOPTION

Adoption, the first stage of the technology transfer process, 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).

Duck (1993) described the need to take people into confidence while introducing any kind of change including the technological changes. He has emphasized the change paradoxes and agreed that trust is hardest to develop and achieve when one needs it most during the change process. Understanding the nature and variety of agendas, which preoccupy potential technology adopters, is arguably a significant form of knowledge for both product developers and, in a wider context, policy makers (Clark *et al.*, 2000).

Hall and Khan (2002) have discussed the concepts of technology adoption, technological standards, and overviewed the contribution of new technology to economic growth. They argued that economic growth can only be realized when and if the new technology is widely diffused and used. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it. An understanding of the factors affecting this choice is essential both for economists studying the determinants of growth and for the creators and producers of such technologies. They discussed the modeling of diffusion and explore the determinants of diffusion and the evidence for their importance.

2.5.1 Need of technology adoption

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 could 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 firms which are able to adopt a particular type of manufacturing technology, becomes quite comfortable in adopting the next level of innovations (Mansfield, 1993). While discussing the acceptance of new technologies by industrialized world, Kuhlmann (1987) identified a few factors related to adoption of new technologies. 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 and Ravichandran, 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, over the entire production supply chain (Greis, 1995).

2.5.2 Technology adoption models

A model for systematic information gathering and thereby reducing the uncertainty in adoption decision has been suggested by McCardle (1985). He suggested a model to quantify the uncertainty and indicated that when to stop the information gathering and made a decision for adoption of a new technology.

A different model for making decision regarding adoption of new technology whose economic value can be gauged directly with certainty, was proposed by Mamer and McCardle (1987). The uncertainty can be decreased in this model by sequentially gathering information, updating his prior beliefs, ideas and opinions in a Bayesian manner.

Inter-organizational transfer and adoption of technology is concerned more with the relative importance of a source of information and the timing of its use. The adopting process has been characterized in a five stage model: (i) awareness, (ii) interest (iii) evaluation (iv) trial and (v) adoption. As far as adoption of new technologies by subordinates in an organization is concerned, Leonard-Barton (1988) observed that managers do influence the adoption process, such influence is not equally dominating under all circumstances. Goodman and Griffith (1991) proposed a multidimensional structure of implementation system. The suggested system has five processes namely, socialization, commitment, reward allocation, feedback and redesign, and diffusion, which are conceptually interrelated to each other at least theoretically.

Small and Yasin (2003) used information obtained from the advanced manufacturing technology (AMT) literature to develop a conceptual framework that seeks to illustrate the impact of the management information systems (MIS) department on the different facets of AMT adoption. A detailed survey instrument was administered to a cross-section of manufacturing firms in the USA to collect the data required to test five hypotheses relating to the efficacy of their framework. The results of their study indicated that the proposed framework by them is particularly useful in explaining the role of MIS departments in firms that are attempting to integrate advanced process and information technologies.

2.5.3 Organizational characteristics for adoption

Munro and Noori (1988) examined the pull-push or integrated theory as it relates to management's commitment to automate their manufacturing process. They used survey results to characterize the variables concerning push-pull theory. In an attempt to avoid the measurement limitations that plagued previous research efforts, their research has incorporated multiple measures of the motivating forces (push/pull) and innovations (automation). ' Their study further proposed a conceptual framework which deals with the factors influencing the decision to automate. The framework, among other things identified the variables influencing technology-push and need-pull.

Veloso and Roth (2001) analyzed how technology, market and policy issues conditioned the adoption of aluminum in the manufacturing of auto engine blocks in Brazil. Due to important weight savings, there is a clear tendency in the auto industry to change engine material from iron and steel to aluminum. This tendency has started in the triad market area, mostly because of scale issues, but the increasing global perspective of the industry is now leading to expansion of these practices into emerging areas such as South America. They used a methodology developed at MIT entitled Technical Cost Modeling to explore the key issues conditioning the adoption of this technology in Brazil and assess potential supplier strategies for this market. Their analysis identified scale of production and local policy conditions, in particular the tax structure and the interest rate, to be the key drivers of differences in component sourcing cost. Their study concluded that casting engine blocks in Brazil seemed viable for production volumes above 65,000 engines per year for foreign investors and 100,000 for local manufacturers.

Brandyberry (2003) examined the relationships between adoption of computer-aided design (CAD) and five organizational characteristics that are likely to affect the probability of a firm adopting an information technology. The organizational characteristics tested are bureaucratic control, internal communication, external communication, organizational innovation, and the firm's size. Results indicated that bureaucratic control, internal communication, and external communication do affect the likelihood of a firm adopting CAD but organizational innovation and organizational size do not. These results suggested there are differences and similarities between the organizational influences associated with classic adoption models developed with emerging technologies and the organizational influences associated with CAD adoption and possibly other mature information technologies.

Astebro (2003) proposed that sunk costs of learning together with the size of output over which these costs are spread, determine both the probability and depth of technology adoption. Depth of adoption described the extent to which firms exploit the advantages of the technology they have adopted. He used national survey data from 271 U.S. plants in 20 metalworking industries to find that plant size but not firm size primarily predicts the probability of Computer Aided Design (CAD) and Computer Numerically Controlled (CNC) adoption. Learning costs appear to be lumpy and occur in short spells tightly connected to the installation of new technology and determine both the probability and depth of adoption. He argued that decisions on learning after adoption seemed considerably more idiosyncratic than the decision to adopt.

2.5.4 Determinants for technology adoption

Siegel *et al.* (1997) examined the issues of adoption of advanced manufacturing technology (AMT) and changes in the composition of the labor force in favor of workers with higher skill levels leading to enactment of employee development and empowerment strategies to promote these changes; using a comprehensive, firm-level survey of technology adoption and human resource management strategies. Their findings indicated that AMT adoption is associated with an overall downsizing of the firm and a shift in labor composition in favor of workers with higher skill levels. They also suggested that "skill upgrading" of the workforce occurs after new technologies are implemented on the factory floor. They also found that human resource strategies that accompany these changes vary by category of technology adoption. Linked AMT appeared to be associated with a greater emphasis on employee empowerment. Conversely, compositional shifts toward managerial, technical, and R&D personnel are greater for integrated AMT. Slowikowski and Jarratt (1997) researched the impact of culture on the adoption of innovation. In an exploratory study, research was conducted with migrants from Vietnam and Poland to examine the impact of culture on the adoption of high technology products. Specifically, data were examined for differences in adoption of these products between Vietnamese and Polish migrants to Australia; and the effect of cultural factors, specifically, traditions, religion and fatality (beliefs about man's inability to control nature), on adoption. Results indicated that culture has an important role in the adoption process of high technology products.

Swan *et al.* (1999) have compared adoption and design of collaborative computer-aided technologies for operations management within manufacturing firms in Sweden and the UK, and examined the influence of technology suppliers and professional associations in shaping these processes. These revealed differences in diffusion with earlier adoption of standardized packages in the UK and a stronger reliance on customized systems in Sweden. Tightly codified 'best practice' solutions have been pushed more strongly both by technology suppliers and also via professional association networks in the UK than in Sweden. This may have generated problems for UK firms because notions of 'best practice' under-emphasize the context sensitivity of the technology and the need for organizational redesign.

Small and Yasin (2000) 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). Their exploratory study examined the relationships between firm-level union status and the adoption and performance of AMT in the discrete parts durable-goods manufacturing industry. Analyses of their sample, which included Chi-square tests, t-tests, correlation analyses and multiple linear regression analyses, revealed a union effect on the adoption of just-in-time technology and a moderately positive union effect on performance. They have discussed the results of analyses of the impact of union status, firm size and several human factor variables on firm performance

Bennett and Vaidya (2002) addressed the question of how enterprises can improve their competitiveness through the acquisition and development of technology, and hence how countries became able to raise the level of industrial development and grow their GDP. They took the example of East Asia to demonstrate how fast economic growth can be achieved through the "stages" approach to technology acquisition and development. They also provided some case studies of technology transfer to China as a means of illustrating how successful transfer can be achieved and the problems that can be encountered.

Parhi (2003) has investigated the impact of geography on the adoption of AMTs in the less developed country context. Taking the Indian auto-component industry as a case for empirical investigation, she showed that being close to customers and machinery suppliers is strongly correlated with a higher rate of adoption of advanced manufacturing techniques.

Faria *et al.* (2003) investigated the main determinants of the adoption of flexible production technologies (FPTs), using a plant-level dataset of Portuguese manufacturing industry. In order to examine the effect of demand uncertainty, they estimated several econometric models for count data. These models dealt with the discrete nature of the dependent variable and firm specific unobservable characteristics arising from the cross-section context. They found that rank effects and technological regimes are important determinants of technology adoption, as put forward in previous models of technology diffusion; demand uncertainty has a significant positive impact on the likelihood of adopting FPTs.

Giunta and Trivieri (2004) conducted a study aimed at identifying the determinants of Information Technology adoption by small and medium sized Italian manufacturing firms

(<100 employees). An ordered profit analysis is conducted on a sample of about 17,000 firms surveyed by the Italian Statistical Institute (ISTAT), using as a dependent variable an index of IT adoption called ITA. Their results showed that firm size, geographical location, functional composition of the workforce, R&D activity, subcontracting, exports and collaboration between firms are all highly significant determinants of IT adoption.

Maheshwari and Ahlstrom (2004) argued that past research on firm turnaround shows that the tendency of an organization to undertake a successful turnaround depends on a complex interaction between action choices in the organization and constraints in the business environment. Their case study extended this line of research by examining corporate decline and turnaround in an environment with numerous challenging environmental constraints: the state-owned sector in India. Using an in-depth case study of a state-owned enterprise in India, their research found that the business environment, the firm's decision-making process, its leadership characteristics, and the stakeholders' responses were all found to influence the firm's action choices and turnaround process. Their study also showed that in addition to the strategic and operational changes so commonly associated with turnaround of firm, the importance of leadership and the basic credibility of the firm's top management with major stakeholders and government officials also play key roles in it.

Kaushalesh Lal (2005) identified and analyzed the factors that influenced the adoption of new technologies in SMEs. Information and communication technologies (ICTs) have been used as a proxy of new technologies. The findings of the study suggested that industry-specific characteristics such as skill- and export-intensiveness have bearings on the type of ICT adoption. The size of operation measured in terms of sales turnover influenced the adoption of new technologies. The results also suggested that there are marginal differences in the labour productivity and profitability of firms that adopted varying degree of ICTs.

Chen (2005) analyzed the determinants of the levels and rates of technology adoption for petroleum refineries that survived the period during which the conditions of product demand and crude oil supply changed significantly. It is evident that firms adopt a new technology when they believe that adoption will have a short term or long term payoff in higher profits. Another major strategic reason can be their interest in gaining experience with the new technology.

Lefebvre *et al.* (2006) investigated the relationship between intangible assets and further advanced manufacturing technology (AMT) adoption in 116 small manufacturing firms. The results of their investigation indicated that the technical skills of blue-collar workers, the influence of customers and vendors, and strategic motivations focused on process improvement and customers are the strongest determinants of subsequent levels of adoption. Further, they showed that strategic motivations moderate the relationships between technical skills and influences and further AMT adoption.

Modi and Mabert (2007) presented a conceptual model of an organization's efforts to improve supplier performance in a dynamic business environment. Then latent variable structural equation modeling was used to test the model. The results suggested that evaluation and certification efforts were the most important supplier development prerequisites before undertaking operational knowledge transfer activities such as site visits and supplier training. Further, collaborative inter-organizational communication was identified as important supporting factor in transforming an organization's efforts to develop suppliers into supplier performance improvements.

Yin and Hu (2007) studied a general dynamic duopoly in which two firms compete in the adoption of current technology with a further new technology anticipated. Three kinds of equilibriums may occur in technology adoption, namely the preemptive, sequential, and simultaneous equilibrium, depending on the level of operating costs and the first-move advantage. It showed that the faster technological innovation encouraged the leader to invest earlier, while induced the follower to invest later.

Fallan (2008) presented a case study of the design and development of a Norwegian crockery series for institutional households. He investigated how this product represented a decisive break with the conventions of postwar Norwegian design and manufacture. He also analyzed how the manufacturer sought to portray this product. The translations of technology, design, identity and consumption showed how an artifact is constantly in a state of transformation.

Asakawa and Som (2008) compared and contrasted what the conventional wisdom suggested regarding the extent of opportunities and challenges of managing R&D as different in China and India from those in the West, and what the realities are in China and India, by drawing on academic literature as well as press articles. They suggested that multinational corporations (MNCs) should not forget the conventional wisdom of managing their innovative R&D policies but should also learn from the unique challenges and capabilities in China and India.

2.5.5 Role of governments in technology adoption

Arvanitis and Hollenstein (1997) evaluated with some methodological considerations, the promotion of AMT by the Swiss government using micro-level survey data. They described a procedure for analyzing the impact of public promotion of AMT on the diffusion of such technologies, based on the estimation of an adoption equation within the framework of diffusion theory by using (primarily qualitative) firm data. Their approach took account of interaction effects between the policy instruments and factors determining the adoption of AMT, as well as the possibility of a reversal of causality between promotion and adoption. Their approach, although conceptually superior to most evaluation work in Switzerland, exhibited several shortcomings at the empirical level, reflecting to a large extent data deficiencies. Moreover, it did not account sufficiently for "soft factors" relevant to the adoption of AMT (e.g. the organizational environment).

Sohal and Maguire (1996) discussed the purpose, pattern and outcomes of investments in advanced manufacturing technologies (AMTs) in New Zealand firms. Based on data collected from 57 firms, they explored the motivation for investing in AMTs, the nature and size of investments, speed of implementation and outcomes including benefits and difficulties experienced. They concluded that although New Zealand firms have made positive investments in a range of sophisticated AMTs, they appeared to focus on operational benefits with little, if any, attention to marketing and strategic benefits.

Goel and Rich (1997) investigated the incentives of private firms to adopt new technologies. They performed econometric investigation on a pooled sample of individual US airline firms over the period 1971 to 1986. They found that firms subject to increased product market competition exhibit a higher propensity to adopt technological innovations.

2.5.6 Timing of technology adoption

Scarso (1996) dealt with the issues related to timing the adoption of a new technology. This was a very important question of strategy which directly affects the firm's competitive capability and whose analysis cannot be adequately faced by conventional capital budgeting techniques. It aims to provide a procedure for deciding on the appropriate adoption time, which is based on the option pricing approach. In particular, since innovative technologies generally disclose a set of strategic opportunities, makes the assumption that adoption occurs when it is possible to profit better from these opportunities. The decision procedure introduced also provides the starting point for developing a practical, option-based framework to formulate a technology strategy. In this perspective, he has proposed a proactive attitude of firms towards the planning and looking for future technology opportunities.

Klenow (1998) modeled a firm's decision of when to update its technology on evidence that productivity growth from learning by doing diminishes as experience accumulates with a technology; and learning by doing is largely specific to each production technology. His model also implied that technology updates are more likely in a boom than in a recession since a high rate of production enables the firm to learn more quickly about new technologies. The forces in this model helped explain some features of plant and industry level data, such as the procyclicality of investment including plant investment spikes and the modest correlation between labor input and productivity.

Baldwin and Rafiquzzaman (1998) examined the determinants of the adoption lag for advanced technologies in the Canadian manufacturing sector. They used plant-level data collected on the length of the adoption lag (the time between a firm's first becoming aware of a new technology and its adoption of the technology) to examine the extent to which the adoption lag is a function of the benefits and costs associated with technology adoption as well as certain plant characteristics that are proxies for a plant's receptor capabilities. Economic theory suggests that the diffusion of advanced technologies should be a function of the benefits associated with the adoption of new technologies. They made use of more direct evidence collected from the 1993 Survey of Innovation and Advanced Technology concerning firms' own evaluations of the benefits and costs of adoption along with measures of overall technological competency. Both were found to be highly significant determinants of the adoption lag. Geographical nearness of suppliers decreases the adoption lag. Variables that have been previously used to proxy the benefits associated with technology adoption—variables such as larger firm size, younger age, and more diversification by the parent firm also decrease the adoption lag—but they have much less effect than the direct measure of benefits and firm competency.

Liu and Li (2003) employed option games approach to present a simplified duopoly continuous time model of technology adoption. In the model, the irreversible investment in adoption of the existing new technology is in strategic competitive circumstances and facing the threat of a further new technology after the competition setting is established. Their results showed that rapid displacement of the technology encourages the leader's investment and discourages the follower's investment. Comparing with the optimal timing without the expectation of a further new technology, the firm hastens to invest when no firm has invested; however, once one firm has invested first, the firm will delay its investment. Using mixed strategy analysis, they derived competitive investment strategies with sequential exercise and simultaneous exercise.

2.5.7 Adoption: measurement issues

Thakur and Jain (2007) 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. For a worldwide perspective, comparison is made between Indian firms, firms in a developed country (Canada), and in a less developed country (China). Contrary to expectation, the average score of AMT adoption degree of Indian companies in their survey was higher than that of all Canadian companies (when unadjusted for size) and of Chinese companies in one of the highly industrialized regions of China as measured in other surveys. This suggested considerable strength of the Indian manufacturing sector. This study found the top six AMTs currently adopted in India are plant certification, computer aided design, local area network, quality circle, MRP/ERP, and wide area network. Clearly four of these top six are directly in the IT area (CAD, LAN, WAN) 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.

2.5.8 Barriers to technology adoption

Mole *et al.* (2001) presented preliminary findings from a European Social Fund project that explores barriers to small and medium enterprises (SMEs) adoption of new technologies. Their research set out to investigate the adoption and effective deployment of technology within electronic and engineering SMEs and its relationship to the firm's strategy and culture. It reviewed the agricultural economics literature on technology adoption and considers whether these findings apply to SMEs in industrialized countries. They reported an in-depth national survey sent to 1000 SMEs within the engineering and electronic industries, which questioned the firms on their size, investment, organizational direction, their adoption of new techniques, and the barriers to their adoption. The method enabled the research team to test the hypotheses concerning information and risk aversion and generalize findings. They analyzed the data using SPSS and multivariate regression analysis and found evidence to support the risk aversion and information hypotheses. Further, they found that SMEs are 'pushed' into adopting new process technologies. Firms adopt process technologies to 'catch up' with competitors.

In summary, the literature on technology adoption is vast. Select studies studying diverse facets of new technology adoption, such as a firm's decision to adopt, determinants, organizational characteristics, timing, location, size and other factors in technology adoption, incentives and policies for adoption, competition and barriers to adoption, and benefits of adoption in competitiveness are included in the above section. Brief results of these studies, many from the developed countries and many from less developed ones, have been discussed above.

2.6 TECHNOLOGY ADAPTATION

Adaptation means to carry out unaided technological design and redesign of the acquired technology. At this level of rooting, the firm is capable of going beyond mere imitation and is able to customize the technology to fulfill needs that it was not originally intended to serve. This requires a keen comprehension of the development theory underlying the technology, its interdependencies with other technologies, and the associated links to strategy (Leonard-Barton, 1990). This deep level of knowledge enhances the adaptability and competitiveness of the firm in a changing environment. Not all technology acquisitions would reach this depth, and in some instances, organizations may have trouble mastering relatively simple operational skills (Steensma, 1996). Adaptation is commonly aimed at making the adopted processes and products more effective in a local environment. An organization can expect little from new technology in general – and imported technology in particular – without developing its capability to modify and improve new technology for domestic applications. Domestic R&D is an important prerequisite for the sound selection, efficient assimilation, and fruitful adaptation of adopted technologies. Adaptation is also an important notion in most theories of human well-being.

Walter's (2000) study dealt with a successful technology transfer process aimed at developing the detail engineering required to set up an oil plant in Tierra del Fuego. Specifically, it analyzed the relationship between the parties involved throughout the cooperation process by which French technological assistance was provided to Argentine engineers. The study of everyday communication among the participants showed that the ‘‘translation’’ required for a successful technology adaptation is achieved when:(a) each partner actually carries out according to contract the complementary tasks for which he is responsible – specific competence.; (b) each party has some basic skills in relation to the specific competences of his partners; in other words, when they share a common technical language which enables communication – generic competence.; and (c) participants ‘‘recognize’’ in both senses of the term their partners’ idiosyncratic work styles. This is when a relational, socio-cultural competence derived from and effective only with regard to the specific ongoing cooperation process, is developed. Teschl and Comim (2005) have revised the original critique of adaptive preferences and compared it with a more detailed analysis of adaptation. They argued that adaptation can be a positive as well as a negative phenomenon and that the adaptive preference critique had a particular narrow view on adaptation.

2.6.1 Adaptation versus cloning

Grant and Gregory (1997) in their analysis have defined a manufacturing process as any repetitive system for producing a product, including the people, equipment, material inputs, procedures and software in that system. An issue of importance in this strategic decision is whether the process should be transferred without modification (referred to hereafter as cloning), or adapted in some way for transfer. Cloning a manufacturing process can maintain commonality throughout a global network of operations, and avoid reengineering costs. Cloning, however, requires robustness to the recipient’s (the host) local conditions and may not allow the exploitation of benefits from local factors of production. The alternative is to adapt some aspect or aspects of the manufacturing process. Through adaptation, the transferor (the home) can take advantage of local characteristics and can facilitate the transfer process. There is a need for a systematic way of assessing a manufacturing process, to ascertain whether cloning at an international transplant is the optimum solution, or whether the benefits deriving from adaptation would outweigh the costs. Their analysis aimed to present a model classifying those factors influencing adaptation to improve fit with local conditions, and those influencing adaptation to facilitate the transfer process. Constructs have been defined which, through classifying these factors, have described a manufacturing process’s overall fitness for transfer. Their analysis concluded with suggestions of how such constructs will help clarify the challenges faced by transfer practitioners. They have also then tested the usefulness of these constructs, and the utility of the factor classification, in a case study.

2.6.2 Need of technology adaptation

The adaptation is commonly aimed at making the adopted processes and products more effective in local environment. Transferred technology cannot be said to be fully absorbed, until the technology has been made indigenous and regenerative, through complete digestion and absorption. Only after such modification is the development of a new improved technology possible

Stohr and Zhao (1997) have proposed a conceptual model for technology adaptation for business process automation that stressed both technology-organization fit and technology-process fit. The goal of their study was to develop a systematic approach that addressed the needs for the organization to be adaptive and for work to be flexible. The technology adaptation model they developed is useful for technology providers in the workflow management area and for business managers who wish to take advantage of the new work-related technologies.The ability to adapt in a rapidly changing and complex environment has become an increasingly important aspect of competitiveness. While firms are free to make their own choices on when, and if, to adopt specific production technologies, they do not individually determine the direction of technological advance. New technology is not necessarily the best strategic choice for the individual firm, but adaptation requires the ability to respond to changes in the terms of competition brought on by other firms' use of new technologies. The strategic use model as proposed by Sonntag (2003) offerd a framework for analyzing current trends in the development and use of production technologies in the context of the relationship of manufacturing strategy to changes in both product market needs and the use of AMTs. Manufacturing strategy forms a critical link not only in firms' ability to adapt to change in their environments, but also in their ability to knowingly shape their futures. The model is a tool for firms to critically examine the possibilities for using new production technologies to competitive advantage.

Andries and Debackere (2007) have hypothesized and tested that adaptation is crucial for the performance (measured as survival) of these businesses, but that this effect is moderated by the (in)dependence of the new technology-based business and by the industry in which it is active. They tested the adaptation-performance hypothesis through a survival analysis of a sample of 117 independent new ventures and business units. Their findings have suggested that adaptation is beneficial in less mature, capital intensive and high-velocity industries but not so in more mature, stable industries. Also, adaptation reduces failure rates in dependent business units as compared to independent ventures. Dangaych and Deshmukh (2004) have reported the findings of an exploratory survey on advanced manufacturing technologies (AMTs) administered in Indian small and medium enterprises (SMEs) of automobile, electronics, machinery, and process sectors. The objective of their survey was to assess the status of AMT, identify AMTs relevant to Indian SMEs, identify competitive priorities, AMT implementation criteria, and assess the degree of investment in AMTs. Responses from 122 companies were analyzed and presented. They have concluded that Indian SMEs are giving the highest priority to quality and the least priority to flexibility. Further, post-implementation evaluation and requirement analysis in AMT implementation have attracted least attention from Indian SMEs.

New ventures as well as new business units experience significant difficulties in finding a viable business model. They often need to adapt their initial business model due to the presence of uncertainty and ambiguity. Technology based companies are confronted with particularly high degrees of uncertainty and ambiguity.

2.6.3 Requirements of technology adaptation

Domestic R&D is a prerequisite for the sound selection, efficient assimilation, and fruitful adaptation of foreign technologies. Priority must be given to the sound and efficient utilization of available foreign technologies. The success or failure of technology transfer solely depends on the accumulated level of technology of a nation. The higher the technological level of the nation, the better judge the nation will be for the assessment and selection of proper technologies (Mansfield, 1988).

The technology selection should explicitly consider the technology content in order to facilitate appropriate technology adaptation in a firm. Productivity is another factor affecting the adaptation decisions but its weightage is not very significant (Madanmohan, 1994). A conceptual model for technology adaptation for business process automation that stresses both technology-organization fit and technology-process fit has been proposed by Stohr and Zhao (1997). They have developed a systematic approach that addresses the needs for the organization to be adaptive and for work to be flexible.

Raj *et al.* (2007) have reviewed the literature on flexible manufacturing systems (FMS) and focused on its implementation. Global competition, advancements in technology and ever changing customers' demand have made the manufacturing companies to realize the importance of FMS. These organizations are looking at FMS as a viable alternative to enhance their competitive edge. But, implementation of this universally accepted and challenging technology is not an easy task. They have reviewed a large number of articles and found that the existing literature lacks in providing a clear picture about the implementation of FMS. They have reviewed the work of various researchers and found that it is really a very difficult task for any organization to transform into FMS on the basis of existing research results. A wide gap exists between the proposed approaches/ algorithms for the design of different components of FMS and complexities of real-life. Besides describing the gap in various issues related to FMS, some barriers, which inhibit the adaptation and implementation of FMS, have also been identified in their review.

Kim and Pae's (2007) recent study has focused on the environmental and managerial factors associated with the successful utilization of new technologies. To this end, their suggested framework has examined the efforts put forth by the two parties involved (the firm buying and the firm supplying the new technology). They have used 112 matched data collected from the suppliers and buyers of the customer relationship management system in business-to-business markets. They found that the perceived turbulence of business environments stimulates adaptive efforts from both the supplying and buying firms, which may lead to a high level of utilization of new technologies for the buying firm.

Vicente (2008) has identified that the over-arching purpose of human factors engineering is to improve the quality of human life, but ergonomics has not been as successful as its professionals would like in effecting societal change, whether it be at the political or corporate level. He addressed this problem, first by identifying a set of general challenges to change, and second by reviewing three illustrative theories of the processes behind large-scale societal change. He argued that past research programs have largely unappreciated 'design' implications that human factors engineers can adopt to increase the likelihood of improving the fit between people and technology in the service of humankind.

2.6.4 Flexible adaptation: strategies and frameworks

Handley and Levis (2001) have designed a model composed of individual models of a five stage interacting decision maker using an object oriented design approach and implemented as a Colored Petri net, in order to evaluate the effectiveness of different adaptation strategies on organizational performance. They have used the concept of entropy to calculate the total activity value, a surrogate for decision maker workload, based on the functional partition and the adaptation strategy being implemented. They monitored individual decision maker's total activity, as overloaded decision makers constrain organizational performance. They conducted a virtual experiment, in which the organizations implementing local and global adaptation strategies were compared to a control organization with no adaptation. The level of tolerance of the organization, the workload limit based on the concept of the bounded rationality constraint, was used to determine when a decision maker was overloaded: the limiting effect of the workload on performance. The timeliness of the organization's response was used in order to evaluate organizational output as a function of adaptation strategy.

Lee and Chen's (2003) inductive research has attempted to explore the dynamics of firm internationalization process, with a focus on a manufacturing firm's first-time foreign entry endeavor. By conducting comparative analyses based on six cases of Taiwanese manufacturing firms who have established production bases in Indonesia and Malaysia, they postulate a conceptual framework entailing relationships among entry decision, implementation strategy, and local adaptation. They highlighted the role that subsidiary's entrepreneurial initiatives play in achieving required extent of local adaptation. Hence, successful implementation for companies lacking sufficient experiential knowledge of internationalization. They based their propositions on the conceptualization and discussed the implications of these qualitative insights, with an expectation of contributing to the extant theories of internationalization.

Tigre and Dedrick (2004) have presented an interesting case study of local factors influencing the adoption and impacts of e-commerce in Brazil. It is a large less developed country in which some segments of the economy are technologically sophisticated while others are quite backward. Based on existing knowledge of Brazil's economic and policy environment and its experience with other information technologies, they have developed three themes that encompass a priori expectations about the diffusion and impacts of e-commerce. First is the expected leadership of the financial sector, driven by strong IT capabilities and a historical orientation toward automation. Next is the leadership of large firms in adopting e-commerce, driven by economies of scale and scope that enhance the perceived benefits of adoption. Third is the relative importance of local versus global forces in driving e-commerce diffusion. Unlike other countries in which globalization is a driver of e-commerce diffusion, Brazil's relatively low international integration of the manufacturing industry, its large size, and its historical inward orientation are expected to reduce the role of global factors as e-business drivers. In addition, they found that the lack of an adequate legal and regulatory environment to support e-commerce has been an important barrier to adoption.

Laosirihongthong and Dangayach (2005) have developed a conceptual framework for new manufacturing technology (NMT) implementation. Scales representing management activities within four stages (adoption, pre-implementation, implementation, and post-implementation evaluation) of the framework have been developed. They used data from the survey of 149 Thai automotive manufacturers to test for content validity and reliability of those scales. Then they applied factor analysis to validate and confirm the construction of the framework of each stage. The result of data analysis indicated four stages of NMT implementation, consisting of (a) determining reasons for NMT adoption, (b) monitoring and justifying whether a certain NMT should be adopted, (c) adapting an existing organizational culture while implementing proper project management approach, and (d) evaluating an effectiveness of NMT implementation.

Koh *et al.* (2005) proposed a new design knowledge expression method called design DNA is proposed in their study aimed at increasing the flexibility of the knowledge structure for accumulation and adaptation. For this, a non-hierarchical knowledge structure is needed. Design DNA facilitates the rearrangement of design knowledge, promotes the flexibility of knowledge structure, and evolves the creative knowledge from similar design. Design DNA is based on layout oriented domain knowledge and function-oriented domain knowledge, which enables generating new design knowledge resulting in new part geometries for given constraints on the part functions. Design DNA is applied to the design knowledge of passenger car parts as an example and shows systematic accumulation and various adaptations of design knowledge.

2.6.5 Role of governments in technology adaptation

Schulze-Cleven *et al.* (2007) have discussed the challenge for the advanced country is to stay wealthy in a rapidly evolving and ever more competitive global economy. As a new digital era emerges and the mechanisms of value creation – that is, the engines of productivity and growth – change in volatile marketplaces, wealthy nations have to find new ways to adapt. Particularly in Europe, successful adjustment has often been posed as a choice between social protection and market flexibility. In their study, they recast this all too common framing and emphasis instead that competitive advantage for the advanced countries may be built through appropriate social policy. Upon clarifying the character of competition in the emerging digital era, they argue that the long-standing strong social protection systems in many European countries could be leveraged to these countries' unique advantage in the emerging digital era. With such benefits as promoting social peace and assisting people in meeting new labour market demands, social protection systems have an important role to play in helping societies reorganize existing economic structures in support of successful adaptation to new competitive conditions. They situate the current dynamics and choices of the digital era by briefly tracing the evolution of historical production paradigms, highlighting for each the relationships between technology, business problems and the resulting domestic and international politics. Then they delineate a newly emerging digital production paradigm and elaborate the accompanying theory of value creation. Driven by the application of distinctive digital tools, firms' internal functions increasingly become products to be bought in the market, products that generate premium prices are turned into commodities, and the sources of differentiation for products, services and their production processes evolve. They also reflected on the lessons of the Danish experience for other European countries' attempts to meet the challenges of the digital era. Lessons about social protection are not only relevant not only for the 'coordinated' economies of Continental Europe, but they apply more widely, even to distinctly 'liberal' countries.

2.6.6 Adaptive learning

Bullnheimer *et al.* (1998) have studied the adaptive behavior of firms that repeatedly have to make a production decision. In a single good market, firms use own experience as well as information gathered by observing competitors to iteratively choose a production technology out of a given set. The adaptive learning of the firms is described in a dynamic model and analyzed in a simulation framework. They showed that a small but positive propensity to imitate is optimal for the firms and yields production efficiencies above 95% of the maximal value. Furthermore, they observed that in a competitive situation firms using optimal propensities to imitate outmatch pure imitators and non-imitators in production efficiency as well as in profits.

Rasiah and Ashish Kumar (2008) have examined differences in technological intensities between foreign and local automotive parts firms in India. Foreign firms enjoyed higher labour productivity, wages, and export, technological and skills intensities than local firms. The econometric results showed a strong relationship between labour productivity and technological intensity. The technological intensity variable (including its components of human resource, process technology and R&D) was also strongly and positively correlated with skills intensity. Foreign ownership was only statistically significant and positive in the human resources regressions. Local firms also showed statistically significant levels of technological intensity (especially in process technology) when competing in export markets, suggesting that foreign firms may offer a competitive and complementary presence to spur local firms' development.

2.6.7 Barriers to adaptation

Madanmohan (2000) has developed a theory aimed at understanding persistent difficulties with efforts at developing plant-level indigenous technology in a less developed country. He identified these major barriers to technology adaptation: (a) inappropriate choice of technology, (b) inadequate planning and support for innovation, and (c) inappropriate process reveal, and (d) product-market mismatch and inadequate market survey.

Murillo-Luna *et al.* (2007) have analyzed the determinants of the strategic environmental behavior of firms and, more specifically, the external and internal barriers that limit and sometimes even prevent the environmental adaptation. Their analysis focused on a sample of industrial firms that have at least three workers and that are located in Aragón, a region situated in the northeast of Spain. From the firms which were sampled, they studied the existence of an underlying structure among the totality of barriers. Finally, they analyzed this structure in order to determine if it has any influence on the degree of proactivity of the firm's environmental strategy.

The literature on technology adaptation covers diverse issues. Select studies and a literature review covering different facets of flexible management of new technology adaptation, such as adaptation needs, performance, flexibility, process, conditions, and factors; adaptation implementation frameworks; role of national policy in adaptation; local and foreign technology intensity; barriers to adaptation; benefits of adaptation; and adaptive learning are included in this section. Besides, many studies included discuss one or more issues of adaptation from one or two countries' or sectors' perspectives

2.7 TECHNOLOGICAL CAPABILITY BUILDING

The research literature available on economics of technical change and innovativeness of firms to effect such changes in respect of developed countries is quite large. In the case of less developed countries, substantial literature has accrued on technology choice and transfer. Some recent surveys in these areas should be useful. However many researchers feel that mainstream economics has relatively neglected several related conceptual issues, the phenomenon of technical change and the associated capability (Freeman, 1994) and hence they are poorly understood (Bhalla *et al.* 1985, Fransman 1985). Broadly speaking, research studies on technological capabilities and change can be classified into two conceptual dimensions viz. developed countries - micro level issues, and macro level issues, less developed countries - micro level issues, and macro level issues. The research agenda in respect of less developed countries shifted from topics such as factor pricing, technology choice, and technology transfer to the real technological change-taking place in them.

The question that arises is 'why can't less developed countries use the considerable research literature that is available on developed countries to make policy that promote firm level technological capabilities (FTC's)? While a few researchers have suggested that the results of innovation studies on developed countries may offer some guidelines to policy making related to technological capability in less developed countries (Fransman 1985, Cooper 1991) many others disagree with the adequacy and appropriateness of such studies to the latter (Textile 1984, Kim and Dahlman 1992, Karagozoglu 1988). The reasons behind their disagreements are perhaps, due to some of the major differences between developed and less developed countries. The structure of industry makes rules of business. Individual income levels, life-style in less developed countries are characteristically different. A bulk of the technologies used in less developed countries are simple and mature because they either cannot have access to emerging technologies or they do not find it useful in their environment (Lee and Choi, 1988). While developed countries move from research to development, and then to engineering, less developed countries largely progress in the reverse direction. Developed countries are largely engaged in risk, skill, effort, and time intensive activities such as new product, process or application development. But, the technological activities of less developed countries, such as adaptation of acquired technologies to local requirements and making minor improvements, are relatively for less intensive in terms of the above-mentioned criteria.

Most developed countries have a sophisticated manufacturing base compared to that of less developed countries. These are adequately supported by sophisticated technological infrastructure in terms of the services related to engineering and construction, consistency, information systems, meteorological and base research facilities etc (Reddy and Zhao, 1990).

Measures or indicators of technological capabilities found in studies on developed countries are not appropriate in the context of less developed countries. In the wake of the differences between developed and less developed countries, and even among the latter, it is necessary to design research studies appropriate to local conditions (Page, 1994).

Several commonly used terms including "technology" "technological change"; "technological capability" and "innovation" are used with different connotations. The way these terms are understood and defined; influences the research designs and their results, policies, and business practices (Reddy and Zhao, 1990). It is very important that they should have some common grounding. In development literature, technological capability represents the abilities of productive enterprises to handle industrial technologies and cope with technological change (Lall 1993). Broadly, they can be referred to as those abilities of an organization, which enable it to undertake various technological activities (Sharif, 1986). Development of suitable indicators to measure technological capabilities enables conducting meaningful research and making policies. The technological capability indicators can broadly be classified as: a) input indicators, including R&D inputs, sophistication of production systems, and length of manufacturing experience; b) Output indicators, that include number of publications, patents, and innovations, production outputs, and exports, and c) a combination of input and output indicators such as measures of productivity. These indicators are largely unsuitable to use in the context of less developed countries due to their peculiar environment (Sharif, 1986)

Besides, capability studies in the context of developed countries have largely focused on "innovation capability" which constitutes only one of the elements of technological capabilities in less developed countries. There are several other elements of technological capabilities (those related to technological acquisition, implementation and utilization), that hold a great potential for development, which less developed countries can not afford to ignore (Lall, 1993). Hence blind acceptance of measures as given by the developed countries is open to questions. In fact, the measures in the case of less developed countries should be for the whole range of firm level technological capabilities and not just one.

A bulk of technological capability literature available on less developed countries has focused on issues and factors at macro level (industry, spectral, national, regional or international level), while issues and factors affecting at micro level (firm level) is negligible and few integrative approaches to address the problem of FTC (Karagozoglu, 1988).

Lall (1992) has reviewed the implications for industrial strategy of research on technological capabilities at the firm and national levels. After exploring the nature and determinants of micro-level technological development, he has set out a simple framework for explaining the growth of national capabilities, based on the interplay of incentives, capabilities and institutions. He proposed that each may suffer market failure and so require corrective intervention. He has described the experience of some industrializing countries to assess the validity of this framework. He has concluded his review by saying that interventions, carefully and selectively applied, are necessary for industrial success.

Rasiah and Tamale (2004) have examined productivity, export-intensity, skills-intensity and technological differences between foreign and local firms in metal engineering, textile and garment, food and beverages plastics and other industrial firms in Uganda using the technological capability framework. In metal engineering, foreign firms enjoyed higher and statistically significant technology index, human resource, process technology and R&D capabilities than local firms. However, the remaining t-tests produced mixed results. Nonetheless, foreign firms enjoyed stronger statistical relationships between the technology index, and productivity and export-intensity, and export-intensity and skills intensity. Foreign firms also enjoyed a stronger statistical relationship between export-intensity, and technology index and human resource capabilities. Overall, the results suggest that local firms can learn considerably from the operations of foreign firms in Uganda.

Rasiah (2004) has also examined differences in technological capabilities between foreign and local auto parts, electronics, and textile and garment firms in Indonesia. Foreign firms enjoyed higher export incidence than local firms in all three industries. Foreign firms enjoyed higher overall technology and HR intensity means than local firms in auto parts and electronics. Foreign firms enjoyed higher and statistically significant process technology mean than local firms in electronics. Foreign firms also enjoyed higher means than local firms in process technology and R&D intensities. The econometric results showed a strong relationship between export-incidence, and overall technological, HR and process technology intensities. Foreign ownership was not only statistically significant and its coefficient positive in the overall sample of the HR regression, but it also emerged that export-incidence was stronger among foreign firms. Export-incidence involving process technology regression was also stronger in the foreign firms' samples.

2.7.1 Technological capabilities for competitiveness

Viana and Cervilla (1999) have studied the technological and competitive capabilities of the Venezuelan manufacturing firms based on a model of managerial dynamics. Their model takes into account a group of variables related to the strategy of the firms as well as variables related to techno-managerial and innovation capabilities. The data gathered was statistically processed by means of factor analysis and hierarchical cluster analysis. The result was a series of indicators of variables related to the strategy of the firm, as well as variables related to techno-managerial and innovation capabilities. A global competitiveness index was constructed in order to locate and to compare firms (and groups of firms and sectors) according to their technological and managerial capabilities. This “competitiveness index” was formed by the three indexes: Capacity (i.e. the managrial and technological capabilities), Innovation (i.e. the change related activities) and Strategy (i.e. the main strategies of the firm). Their results made a reflection about the strengths and weaknesses of the firms in a sector, in order to formulate managerial strategies and industrial policies directed to improve the competitiveness, so that they can face with success the enormous challenges outlined in a new environment characterized by quick technological changes and globalization.

Rocha (1997) has provided evidence on the role played by firms’ technological competencies in the determination of their intensity of cooperation with other firms. Using a database composed by patents jointly filed by two or more firms in the European Patent Office, the study found no support for the hypothesis that in order for firms to increase their rate of cooperation they should expand their R&D expenditures; held that technological cooperation is explained by the need of the firm to acquire complementary competencies; concluded that cooperation is an alternative technological strategy for those firms that have adopted lean production to overcome obstacles posed by the cross-fertilization of technological fields; and showed that Japanese firms have a higher level of cooperation than Western ones. This latter feature may be explained by greater level of productive specialization of Japanese firms.

Battisti and Pietrobelli (2000) have developed a theoretical framework to analyze intra-industry gaps in technology and have tested it with enterprise-level data from a developing country, Chile. Their analysis focused on five major sectors: food processing, textile and garments, woodworking, metalworking, and paper. They found that firms with different levels of technological complexity co-exist within same industry, and differences in technology are discrete, with different clusters haring similar characteristics within the same industry.

Kim (2000) presented an analytical framework on how industrialization takes place through the development of technological capability in interactions with the evolution of market competition, government policy, corporate strategy, and social culture in the context of less developed countries. This framework is applied to Korea to describe the dynamics of technological learning in the industrialization process. The Korean experience suggests a set of implications for other less developed countries, such as, export promotion as an effective policy instrument for creating competitive stimulus for firms to expedite technological learning; expanding and improving quality of education as a basic government measure for helping firms build an adequate existing knowledge base; a liberal policy on brain drain in the early stage of industrialization can benefit less developed countries in the long run; a high tacit knowledge base is a prerequisite to effective technological learning; technology transfer should evolve over time, as industrialization progresses; intensity of effort as another prerequisite for building technological capabilities for industrialization; public technology policies should evolve over time to respond to changes in market and technology environment; and the role of government research institutes should evolve over time.

Wignaraja (2001, 2002) has explored the role played by internal technological factors on the exporting behavior of enterprises of different size classes in the Mauritian garment industry by constructing a technology index and conducting econometric analysis on factors affecting enterprise-level technological development and export performance in a sample of Mauritian garment enterprises. The econometric result showed that firm size, technical manpower, training expenditures and external technical assistance are positively related to the technology index. This confirmed that investments in human capital and seeking information, both facilitated by size, improve technological performance. This was strengthened by the fact that the technology index and foreign ownership have positive and statistically significant effects on export performance of each firm. The mathematical model of technology index was found to be a robust tool of empirical research and can be used to analyze the technological record of enterprises in adjusting less developed countries.

Chandra and Sastry (2002) have presented findings of the second national survey on the competitiveness of Indian manufacturing. They have developed hypotheses on the competitiveness of firms in the manufacturing sector and addressed some key questions on the characteristics of world class firms in India. They have also analyzed the processes and practices that such firms have adopted to become world class. More important, they have highlighted firm level practices that are preventing Indian firms from becoming globally competitive. Their findings point towards three distinct aspects of manufacturing management that define the capabilities of the firm, i.e., strategies related to dynamic control of shop floors, network linkages and innovation. They have found that those firms that build distinctive technological and managerial capabilities in these domains are able to compete globally. They have provided a comparison with manufacturing capabilities of competitors in China and drawn lessons for organizing large scale manufacturing. They have also provided an assessment of the changes that have happened in manufacturing priorities and strategies in India since their last survey conducted in 1997 and highlighted the implications of these changes.

Kumar and Jain (2003) have presented findings of field research to study the status of new technology commercialization practices in India. Their focus was on the parameters that influence the decision regarding commercialization of new technologies and the success of new technology ventures, the efficacy of existing financing/support mechanisms and the further actions required by stakeholder agencies, viz., industry, technology institutions, financial institutions and the government for further development of commercialization of new technologies in India.

Viljamaa (2007) has examined the emergence of university–industry partnerships in the motor sports industry cluster located in the Charlotte region of North Carolina, USA. Despite little industry demand for the local engagement, the universities and community colleges started to approach the industry in the late 1990s and recently several new programmes of motor sports-related research and education have been initiated. During last few years, the regional and state governments have also started to play a role in building up support for the motor sports industry. This process has largely been influenced by the ideas of knowledge economy and innovation as an interactive process, by the ideas of the wider social and economic role of universities, and by increase awareness of the relevance of the motor sports industry for the regional economy. Charlotte's motor sports industry is an interesting example of how a previously rather craft-based industry transforms into one in which technology, innovation and creativity play a key role in firm performance. However, the strategy for building up regional capabilities and relationships necessary to support the increased technological intensity of the industry has been slow to develop. He addressed the important question of how the universities together with other research and educational organizations can build collaboration with an industry that has traditionally prospered in the region without any links to them, but which in the face of technological challenges needs to reach out to access cutting-edge knowledge and highly qualified personnel.

Swink *et al.* (2007) have focused on the integration of strategic objectives and process knowledge that a manufacturing factory collects from its external interfaces. Using data from a variety of manufacturing industries, their study examines four different types of strategic integration at the manufacturing plant level. They used a path analytic approach to simultaneously assess the contributions of the various types of integration to manufacturing-based competitive capabilities and business level performance. In addition, they have examined the intervening roles that manufacturing-based competitive capabilities play in mediating the relationships between strategic integration and business performance. They found that each type of integration activity has unique benefits and detriments. These findings extend prior studies of manufacturing and supply chain integration by broadening the theory relating to strategic integration. Their results also provide implications for manufacturing managers who seek to design integration policies and associated resource deployments.

2.7.2 Measuring technological capabilities

Hobday (2002) has developed a framework for technology needs assessment (TNA) to identify technology needs and priorities of less developed countries in order to ensure successful technology transfer. He has developed the framework from a local capability point of view of less developed countries. He has covered both dimensions of technological capability viz: (a) the capability to develop strategies and manage technological acquisition, use, and further development; and (b) the detailed engineering capacity needed to acquire and develop specific technologies. H has recognizes the first dimension as the most important and has offered a framework and specific tools for technology analysis needs of less developed countries.

Three versions of TNA have been developed by him: at national level, at sector level, and at the enterprise level. TNA at firm or enterprise level has been discussed in detail in the 2001 CAPTECH Manual (Bessant *et al.* 2000). To complement the CAPTECH Manual, Hobday has developed a Self-Assessment Technological Capability Audit Tool. Using this audit tool, a firm can first calculate its overall technology capability level, and secondly identify detailed strengths and weaknesses according to nine sub-categories of technology capacity. There are 24 questions in the audit tool and responses are analyzed on a four point scale.

2.7.3 Building technological capabilities

Wei (2000) has examined the questions of (a) how in a rural zone, has indigenous technological capability been acquired, and (b) what role is played by municipal governments in the process, and (c) what kinds of policies were helpful in fostering acquisition of technological capability in special economic zones (SEZs). He concludes that economic growth does not necessarily lead to structural transformation in SEZ. These zones contribute to, and are in turn affected by, the process of development within a country.

Aminullah (2000) has attempted to understand the structure underlining the weakness of the Indonesian economic development strategy in a systemic perspective. The explanation assumes the importance of industrial technological capability within the framework of the techno-economic structure. The results of a simulated model of techno-economic administration show the weakness of the industrial technological capability. This is a determinant factor of low industrial efficiency that brings about the current discontinuity in economic progress. On the basis of policy simulation, there are techno-economic policy initiatives needed to strengthen the future industrial technological capability. It implies that there is a need to shift from economic towards techno-economic policy orientations. Failure to confront this policy issue will make a new cycle of economic crisis possible.

Jiang (2000) has analyzed firm’s technological capability enhancement in highly competitive and demanding business environment as a strategic planning. The technological capability, which refers to the firm’s knowledge and capacity embedded into the individual and organizational resources, is one of the most important potentials for firms to gain the sustainable competitive advantage and high benefit return. With the enhancement of technological capability, the firms gain the sustainable economic rectum in the long time. First, they have proposed the implicit logic between the technological capability enhancement and the growth of benefit return. Second, the paper discussed the accumulative rule of the firm's technological capability from four dimensions: humanware, orgaware, technoware and inforware. It adopted the economic cybemetic model to explore the interactive functions between the technological accumulation and economic return. Third, it used the case of Hangzhou Machine Tool Company to analyze the economic perspective of technological capability improvement.

Oner *et al.* (2003) have assessed technology management capabilities and draw capability profiles of firms in automotive, white goods and electronics industries in Turkey. Using a capability assessment process model entitled 'TPMCPM', their study diagnoses the actual source of deficiency in management of technology processes and makes recommendations for enhancement of the technology-related practices.

Techakanont (2002) investigated the process of inter-firm technology transfer (TT) in Thai automobile industry in his doctoral dissertation and concluded that once a firm decides to invest in, it not only has to carry out the process of intra-firm TT, but also of inter-firm TT to another country. Techakanonta and Terdudomthamb (2004) have further investigated the evolution of 'inter-firm' technology transfer in the Thai automobile industry, which has gradually been integrated into global production network of some specific automotive models (one-ton pickups). They have discussed the linkage between the role of automobile assemblers in transferring technology and the way their strategic changes bring about heightened demands on the technological capacity of suppliers and the contents of technology transfer. With higher competition at the global level, local suppliers are required to improve their technical and managerial skills, especially in the area of 'product engineering' capability. They have examined the ways local firms have adapted to these changes in their environments, as well as the ways they utilize inter-firm relationship with automobile assemblers as a means to improve their own technological capabilities. They have also discussed dynamic process of capability formation in local parts firms, through intensive efforts and learning inducements brought about by inter-firm relationships.

Gammeltoft (2004) has reported from a broader study of development of technological capability in the Indonesian electronics industry with particular focus on local companies. He has discussed the concept of 'technological capability', proposed operationalization of the concept, devised a model of capability development at the firm level. An empirical survey of the industry was carried out on these bases. The Indonesian electronics industry is conventionally depicted as being 'dual' but this study establishes that not just two but a larger number of qualitatively different industrial segments should be recognized. Capabilities and the ways capabilities are developed are analysed for companies belonging to these different segments. He found that local companies in several respects come out as more technologically capable than usually assumed.

Yu *et al.* (2004) try to explore the technological capability development process by latecomer firms, especially those in big emerging countries. Based on the insights summarized from the case study of China's telecommunications manufacturing sector, they have shown how the latecomer firms can penetrate the technical cycle and gradually cultivate their own technological capability in the local market. Four continuous inter-linked capability building strategic processes, namely: core acquisition, gap identification, specific exploration, and quick provision have been mapped discussing various activities involved in each of these processes. This process model has the advantages to integrate strategic process thinking and actual operations of the latecomer firms facing the global competition. Finally, they have proposed a research program to test the model.

Oyelaran-Oyeyinka and Lal (2004) have examined through field data, the ways in which medium and small enterprises in selected less developed countries learn to use and augment their core capabilities with new technologies. They presented three findings. First, there was clear evidence of increasing complexity in the adoption and use of ICTs among firms in less developed countries. Second, climbing the technological ladder required skills upgrading through explicit learning of the new technologies. Third, firm performance was highly associated with learning capabilities, levels of technology, and a host of firm-level knowledge, skills and experience. Their study formed that across countries and sectors, non-formal learning is the dominant form of mastering new technologies. However, formal local and overseas training are positively associated with increasing technological complexity. There is also a close correlation between technical complexity of firms' internal ICT tools and available telecommunication infrastructure.

Raghavendra and BalaSubrahmanya (2005) have explored the influence of various learning mechanisms on the acquisition of technological capability in small industry clusters through a field study conducted in two foundry clusters in south India. They probed whether the collective efficiency through higher inter-firm linkages and cooperation with firms/agencies within a cluster as well as outside the cluster, lead to higher technological capability. Seven variables affecting technology capability building were employed to in the study, namely: age of the firm, education of owner/manager; working experience, horizontal collaboration, vertical collaboration, mobility of skilled labour, and external technological assistance and information flow. They developed suitable proxies to measure technological capability and the learning mechanisms, thus facilitating quantitative analyses. The evidence suggests that collective efficiency, either in the form of horizontal cooperation or vertical cooperation, has a significant influence on technological capability. However, it is the factors like proximity to markets, nature of the cluster – homogeneous or heterogeneous, that appear to reinforce the kind of cooperative efforts, horizontal or vertical, that are more conducive to the acquisition of technological capability in firms.

Daniels (2005) has systematically identified conditions in lower income countries (LICs) that would likely promote, and benefit from, the pervasive adoption of material- and energy-saving technologies. He has explored empirical link between technology capability and human development index. He concluded that a green socioeconomic paradigm may well provide a viable alternate approach in the LICs. He has suggested that the main advantages of this are derived from related resource efficiency gains and reductions in socioeconomic metabolism, and the benefits of a relative production factor shift toward labour and away from materials, energy and environment-intensive capital.

Sherifaw (2007) has examined the entry, survival and exit patterns of Ethiopian manufacturing firms using census-based panel data for the period 1996 to 2002. His study revealed an underlying market selection mechanism that reallocates resources towards more efficient producers and forces inefficient firms to close down. This process also contributed to aggregate productivity growth although the manufacturing sector continued to lose productivity due to intra-firm productivity decline. He also explored the accumulation of technological capabilities and their role in firm-level productivity growth. Data from a sample survey showed a very sparse incidence of innovative activities in Ethiopian manufacturing. Nonetheless, firms that engage in building technical capabilities exhibit higher levels of productivity after controlling for other firm characteristics. He concluded that while markets contribute to aggregate productivity growth by exerting competitive selection, long-term industrial competitiveness in less developed countries could be stifled because of inadequate technological learning.

2.7.4 Role of governments in building technological capabilities

Caloghirou *et al.* (2000) have examined the process of technology transfer and associated learning effects experienced by the Greek telecommunication equipment manufacturer Intrakom as a result of its involvement in public procurement processes and the technological shift towards software-driven digital switching and transmission systems. Drawing upon the role of Government procurement as an instrument for industrial policy and the learning potential of a technology transfer process, they argued that the Public sector's industrial policy considerations, exercised through the procurement practices of the Greek Public Telecommunication Operator, as well as Intrakom's own timely focus in establishing a long-term collaboration agreement with a leading international vendor Ericsson played a catalytic role in the accumulation of domestic capabilities in the manufacturing of selected telecommunication equipment products.

Huq (2004) has made an attempt made to highlight the case for explicit, coherent and effective technology policy as the way forward in rapidly globalizing economies, especially those in the developing world. In this regard, his paper invokes some recently published evidence from three countries of the Indian subcontinent, namely Bangladesh, India and Nepal, all of which are low-income developing countries. He concluded that technology policy is destined to promote enterprise culture, R&D and innovation initiatives would ultimately enable developing countries to produce global competititve players in various areas of economic activity. On the other hand, he argued that the failure of government policy to address local problems in the context of developments in the wider global economy will see low-income countries locked into vicious circle of poverty.

Intarakumnerd and Virasa (2004) have focused on the significant issues of technological capability development of latecomer firms, and government policies enabling such firms to attain certain level of technological capability. They surveyed and conducted case studies of manufacturing firms in Thailand to substantiate and investigate the process of technological capability development of latecomer firms. Their analysis portrayed a dynamic view of technological capability development that comprises three key elements namely strategic capability, internal capability, and external linkage capability, reported as a "Development Staircase" of a firm's technological capability. They subsequently, discussed and suggested a tentative taxonomy of government policies and measures to support firms' technological capability development through the development staircase.

Sadoi (2008) has examined the process of technology transfer from foreign to local firms in the automotive parts industry in China, focusing on parts localization processes and technical capabilities. Using survey and case study information, his study compares parts localization and technical transfer programmes in China with the experience of Malaysia's Proton. The results show that Chinese firms have achieved localization much faster than Malaysia's Proton largely due to the strategic nature of government policy on foreign direct investment (FDI) and technology transfer.

Government of India in its ten-year Automobile Mission Plan (2006) has clearly identified development and assimilation of technology for ensuring availability of best quality product at lowest cost to the consumers. "The Government recognizes [the] […] role [of technology] as a catalyst and facilitator to encourage the companies to move to higher level of competitive performance. The Government wants to create a policy environment to help companies gain competitive advantage. The government policies target to encourage growth, promote domestic competition and stimulate innovation." India - Ministry of Heavy Industries and Public Enterprises (2006).

2.8 LIMITATIONS OF EXISTING APPROACHES

It is very surprising to learn from the literature, that not much has been written about the management of technology adoption and adaptation for building technological capabilities in less developed countries (as compared to developed countries) in general and India in particular. After the liberalization of Indian economy and globalization of trade, commerce, and industry, being initiated in 1991, there had been a rush for technology transfers from developed countries. Indian management researchers have started penning down the things but only in a very limited domain. There have been some stray cases available of technology transfer in the literature which do not reflect fully the motives behind adoption of technology from abroad, and the subsequent experiences in developing technological capabilities. There has been a lot of research done on technology adoption, technology adaptation or building technological capabilities independently, but the research regarding the linkages between these is missing. So this research has been planned to develop a conceptual framework to build technological capabilities through flexible management of technology adoption and adaptation.

A comprehensive attempt has been planned for analyzing the cases of technology adoption and adaptation for building technological capabilities in manufacturing firms for a large country such as India.

2.9 CONCLUDING REMARKS

A selective review of available literature in the field brings out a few points relating to management of new technology in a logical manner. These include lack of understanding of what to expect and what not to expect from technology adoption and adaptation, role of flexibility in technology adoption and adaptation, and the knowledge of technological capability building for a given organization.

This review is an attempt in this direction in the Indian context to cover a few of these points, particularly those relating to organizational and managerial issues of managing new technology adoption and adaptation for building technological capabilities in manufacturing industry in a flexible way. Based on the literature reviewed above, a few important factors concerning technology adoption and adaptation have been identified. A conceptual framework representing the cyclic process of building technological capabilities through flexible management of technology adoption and adaptation has been derived using factors identified in the literature. In this framework, the technological capability building in a firm process starts from technology adoption. Technology adaptation is the next stage in this cyclic process. Facilitated by technology adoption and adaptation, a firm develops its technological capabilities, and this completes one cycle. By virtue of acquired technological capabilities, the firm then proceeds for adoption of next level of technology, after the adaptation of which, technological capabilities of the company are further developed and the cycle continues. Graphical representation of this process is shown in Chapter 6 (figure 6.4). The factors identified were also taken into account for carrying out empirical study and analysis, and for case studies.

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 flexible management of technology adoption and adaptation 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; 1997b, 1999).

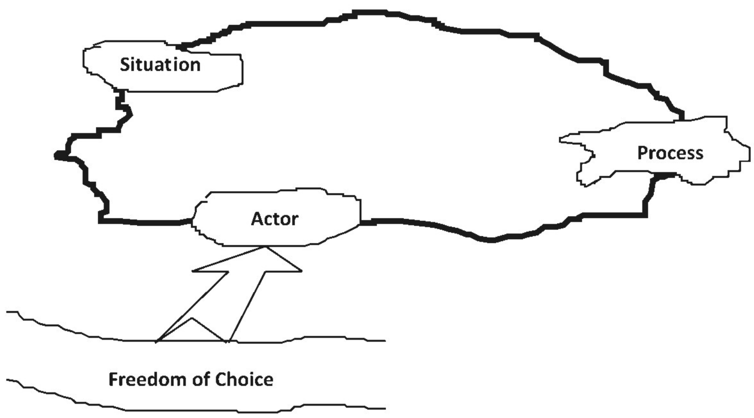

Figure 3.1 Flexible Systems Management Paradigm

SAP framework, as applied to this research, is as under. The ‘situation’ aspect comprises of the present industrial situation in manufacturing industry, whereas the organization constitutes the ‘actor’ aspects. The role of new technology adoption and adaptation practices in building technological capabilities 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. 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 technological capability building 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 technology adoption and adaptation has been taken, therefore, the SAP-LAP analysis is static.
- Since only one conceptual framework representing the approaches for building technological capabilities has been developed, the SAP-LAP analysis – on which this framework is partly based – is singular.

3.3 PHASES OF RESEARCH

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

3.3.1. Clarifying the context

Literature on management of adoption and adaptation of advanced manufacturing technology (AMT), technological capability, flexibility and success due to AMT implementation has been reviewed in detail. This has essentially focused on the need of flexible management of new technology adoption and adaptation. Case studies have been reviewed in order to be apprised of the results achieved by different researchers in different situations.

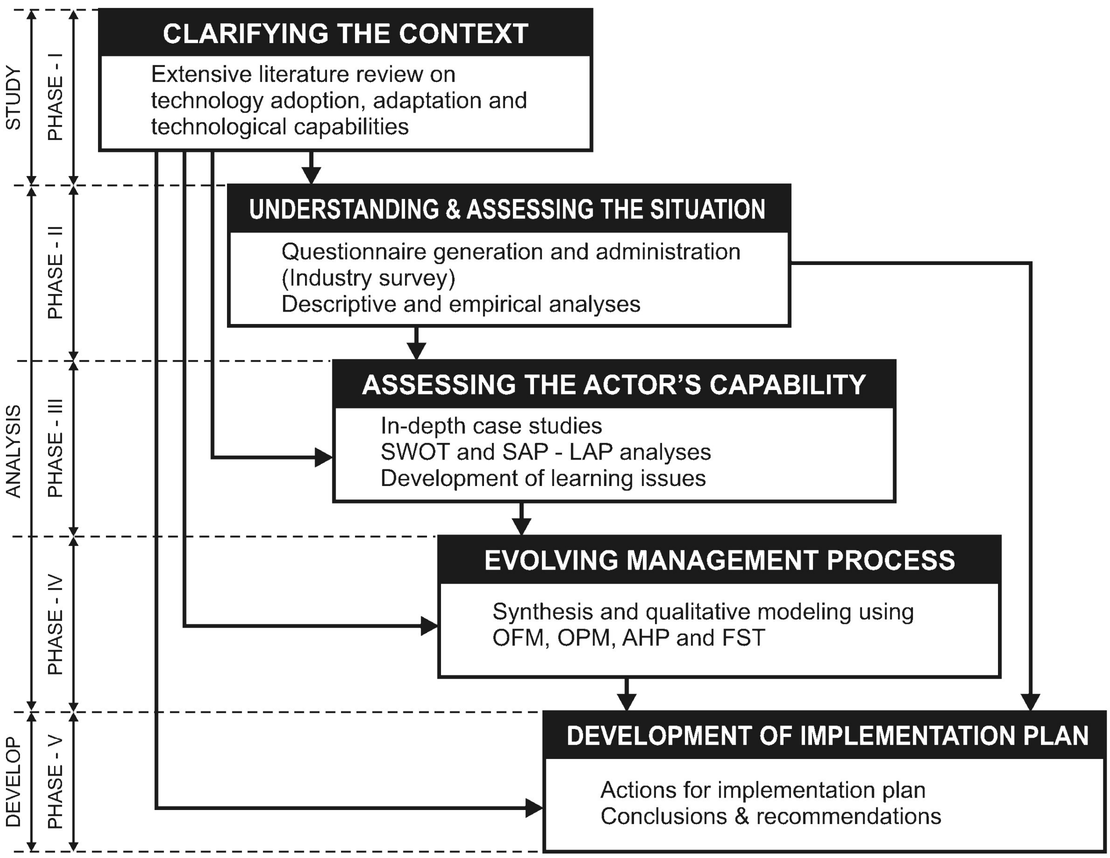

Figure 3.2 Design of the study

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 technological capabilities 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. Besides, it also considered the most important type of survey-based research in terms of 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.

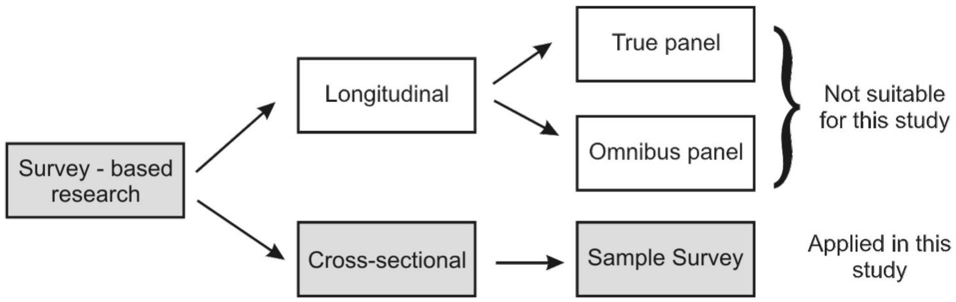

Figure 3.3 Overview of survey based research

Survey Methodology: A survey of various manufacturing organizations, involved in building technological capabilities has been taken up by using a particularly designed questionnaire. Special emphasis has been given to seek information related to current practices of the organizations in the process of technology adoption and adaptation, status of technological capabilities and the status of various factors affecting technology adoption and adaptation. The questionnaire has been designed after extensive literature review and validated through peer review from academicians and practitioners from the industry.

In the questionnaire, objective type questions containing multiple choice answers were framed on all aspects of management of technology adoption and adaptation and use of flexibility in them. 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 technological capability has been determined by using a self assessment technological capability audit tool in which nine sub-dimensions of technological capability have been measured. Relationships between new technology adoption and adaptation; and technological capabilities have been explored in the study. The organization's objectives of adoption and adaptation of technology have also been analyzed 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 factors affecting technology adoption and adaptation on buildingtechnological capabilities. In data analysis, independent and dependent constructs (variables) have been formulated based on literature review and the objectives of this research. Constructs relating to technological capabilities, success due to technology adoption and adaptation and flexibility were categorized as dependent variables whereas factors affecting technology adoption and technology adaptation were categorized as independent variables in the analysis. Five distinct technology adoption constructs that are likely to influence the technological capabilities objectives include role of government, impact of globalization, role of top management, manufacturing strategies and technology adoption policies of the company, and human factor. Further, technology adaptation based constructs comprise of role of government, role of top management, employees' education, in-house R&D, and technology adaptation policies of the company. The effect of these factors on technological capabilities, success and flexibility has been assessed.

The convergent and discriminant validities of the constructs and their measures have been carried out. Various statistical tools and techniques have been employed using SPSS software to predict the results. Convergent validity assesses the degree to which measures of same concept (construct) 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 analysis refers to testing statistically whether two constructs differ significantly from each other.

Since the interest of this research 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 deemed to be 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 obtained in the SPSS output satisfies these conditions and is used for interpretation. Further, computation of canonical cross-loadings has been done, as a direct measure of the independent–dependent relationships by eliminating an intermediate step involved in conventional loadings.

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 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 technology adoption and adaptation which have been reflected as the potential areas requiring further investigation.

To carry out case studies, the basis for selection of industrial unit(s) has been:

i) The unit(s) to be a representative of the manufacturing industry i.e. most of the operations and process are prevalent in that unit.

ii) It has requisite activity going on pertaining to the potential areas of technology management as reflected by the results of the survey.

iii) The unit is forthcoming and cooperative for conducting case studies.

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

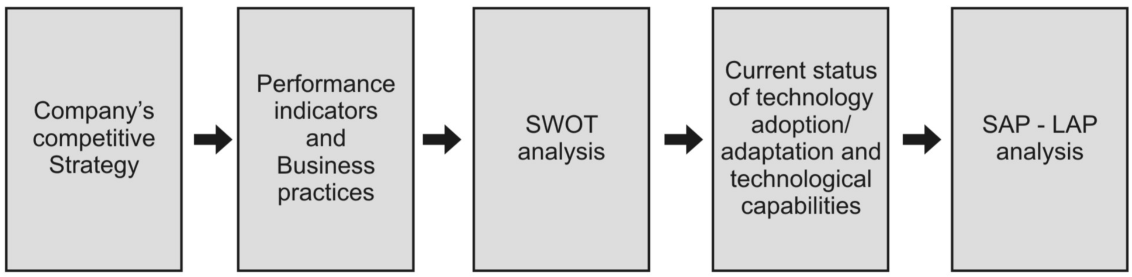

Figure 3.4 Methodology for conducting the case studies

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

Table 3.1 Case study methodology and analysis

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 of the organization over time.
3	Step-III: Status and analysis of the practices followed by the organization for new technology adoption and adaptation. Techniques used: Consolidating the technology adoption and adaptation process and assessing the strategy adopted by the organization.	To study the effects of various practices followed by the company on its technological capabilities.
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 management of technology adoption and adaptation 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 learnings 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.

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

Finally, the critical learning issues from 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 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 180 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 four point (1–4) Likert-type scale has been employed for all item measures in the questionnaire. 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 later 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 Technological Capability have been adopted from existing scales used for Self Assessment Technological Capability Audit Tool (Bessant et al, 2000). Existing literature has been also consulted to develop item measures for the Success due to implementation of advanced manufacturing technologies (Chen et al, 1992; De Meyer et al, 1990; Hall and Nakane, 1990; Sethi and Sethi, 1990; Tidd, 1991). Scale items relating to flexibility have been adopted from various researches carried out in this area Individual item measures for independent variables have been developed in the study.

The questionnaire consists of five sections i.e. Section A, B, C, D and E. All Questions are multiple choice and close ended on a scale 1 to 4. Section A was designed to get general information about the respondent and the organization e.g. authorized capital, product mix, number of employees, scale, collaborations, turnover, profit, number of competitor, market share and investment made in specific areas. Information on priorities of objectives set by an organization was also sought in this section. Section B included questions which seek technical information on the current status of new technology adoption, practices followed in its process and importance of various factors affecting it. Later in this section, information on the status and role of technology adoption policies in respondent industry was also sought. Section C covered the similar aspects, but with reference to technology adaptation. It contained questions to determine the practices used in technology adaptation process, how changes are carried out in organizational structure, layouts, manufacturing processes and manpower etc. Later in this section, information on the status and role of technology adaptation policies in respondent industry was also sought. Section D contained a Self Assessment Technological Capability Audit Tool consisting of 24 questions and some other factors which reflect the success achieved due to adoption and adaptation of AMT. These 24 questions of technological capability audit addressed the nine dimensions of technological capabilities and the responses to these questions determined the current status of technological capability. Finally, section E was designed to find out the extent to which a firm’s objectives are met.

3.4.1 Questionnaire pre-testing

To ensure the relevance and the effectiveness of 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 was 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 Cronbach's Alpha 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 instructions was undertaken. The covering letter and the questionnaire is given as Appendix-A. The questionnaire served the purpose of revealing the exploits of Indian entrepreneurs with technology adoption and adaptation practices and highlighted its contributions in building technological capabilities.

3.4.2 Sampling and data collection

Data relevant to adoption and adaptation of new technology, success, flexibility and technological capabilities were collected from senior executives in manufacturing firms across North India. The questionnaire alongwith a postpaid reply envelope was mailed to 400 Large and Medium scale manufacturing industries chosen at random from among the membership of the Confederation of Indian Industry (CII). 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. Seventy eight responses were received, constituting a responses rate of 19.5%. This compares well with the responses rates for studies in operations management (Handfield 1994, Suarez et al. 1996). Elimination of unusable or incomplete responses resulted in 70 cases.

The focus of the study is on large and medium-scale manufacturing enterprises of North India. 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.

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 ANALYSIS

For a closer examination of relationships between individual dimensions of dependent variables with the independent variables, the multiple regression analyses are done using the stepwise method. Multiple regression analysis is a statistical technique that can be used to analyze the relationship between a single dependent variable and several independent variables. Stepwise estimation is the perhaps the most popular sequential approach to variable selection. This 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 ON FLEXIBLE MANAGEMENT OF TECHNOLOGY ADOPTION AND ADAPTATION

4.1 INTRODUCTION

In this chapter, the results of detailed survey conducted in various manufacturing enterprises in the northern region of India covering the states of Punjab, Haryana, Himachal Pradesh, Rajasthan, Uttar Pradesh, Delhi and Union Territory of Chandigarh have been presented, analyzed and discussed. The survey has been limited to those medium and large scale manufacturing enterprises of the northern region, which are in process of acquiring, developing or utilizing the new technology. The survey has been conducted to determine the present status of technology adoption and adaptation practices, flexibility incorporated in their management process and its effect on technological capabilities of these organizations.

4.2 DESCRIPTIVE ANALYSES

Among the 70 (100%) respondents, 13% were the automobile manufacturers, 39% industries were the automobile component manufacturers, 37% industries were consumer goods manufacturers and remaining 11% were process industries. The industry-wise breakup is shown in figure 4.1.

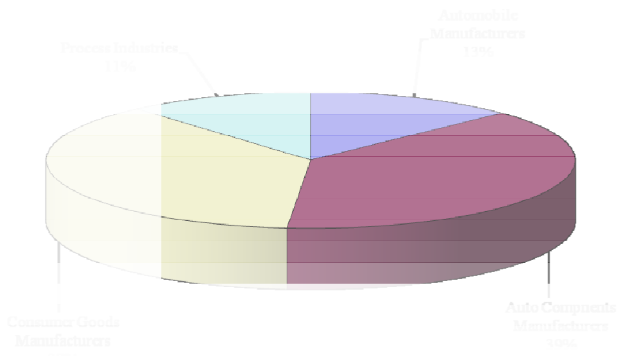

Figure 4.1 Industry-wise breakup of respondents

Figure 4.2 indicate that among the respondents, the 29% industries have authorized capital less than Rs. 100 crore, another 29% have between 100 to 250 crore, 13% have

250 to 500 crore and remaining 29% have authorized capital above Rs. 500 crore. It implied that 29% industries (with authorized capital less than 100 crore) are medium scale industries where as all other are large scale industries.

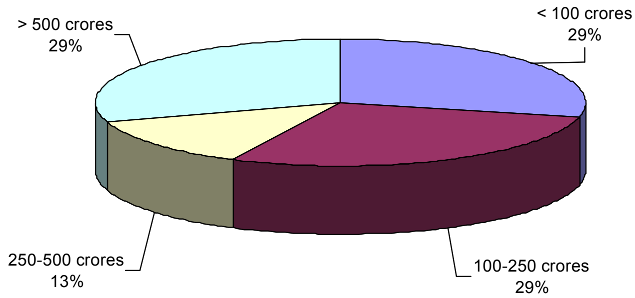

Figure 4.2 Turnover-wise breakup of respondents

Figure 4.3 show that out of 70 responses, the 11% industries are less than 5 years old, another 11% are between 5 to 10 years old, 10% are between 10 to 15 years and remaining 68% are more than 15 years old.

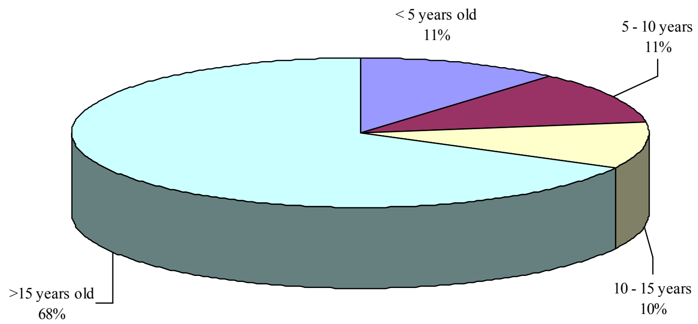

Figure 4.3 Age-wise breakup of responses

4.3 STATUS OF NEW TECHNOLOGY ADOPTION

Manufacturing has been evolving over the years as different needs and technologies arise. India, a large developing country with a population of more than 1 billion, has experienced fast and stable economic growth in the past decade. The customer of the twenty-first century, demands products and services those are fast, right, cheap and easy. The quest for lower operating costs and improved manufacturing efficiency has forced a large number of manufacturing firms to embark on advanced manufacturing technology (AMT) projects of various types. AMTs have been heralded as new way for manufacturing companies to gain a competitive advantage. The dramatic developments in AMT at various organizational levels can be attributed to numerous benefits that improve the competitive position of the adopting companies. AMT impact not just manufacturing, but also the whole business operations, giving new challenges to a firm's ability to manage both manufacturing and information technologies. This survey has highlighted very interesting results related to the current status of technology adoption. In this section the data has been collected from the organizations to understand and explicate the process of new technology adoption as a part of their business strategy.

Out of the respondents companies, 7% companies rarely adopt new technology, 16% adopt sometimes, 47% normally adopt where as remaining 30% always adopt new technology, as shown in figure 4.4.

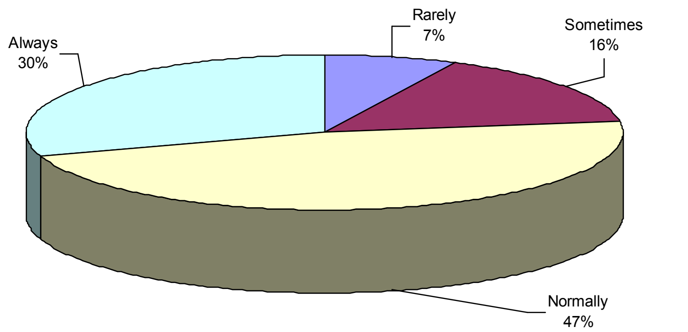

Figure 4.4 Frequency of new technology adoption

As depicted in figure 4.5, out of these respondents companies, 17% companies adopt new technology when there is dire need of it, 29% adopt new technology when its performance has been proved, 21% adopt when it gets popularity and remaining 33% adopt new technology immediately on its availability.

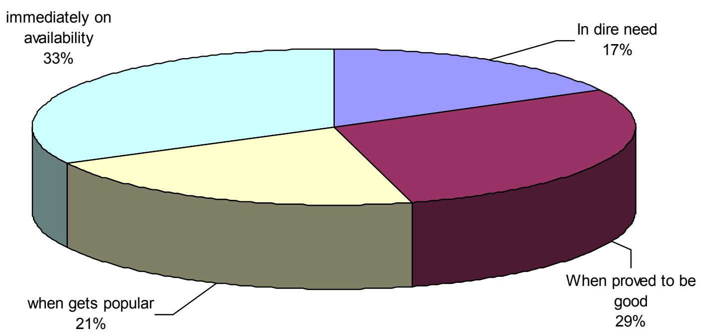

Figure 4.5 Timing of new technology adoptions

Among the respondents, 20% companies adopt new technology only for most critical processes, 17% adopt for some of the important processes, 44% adopt for most of the important processes and remaining 19% adopt new technology for all processes and operations, as shown by figure 4.6.

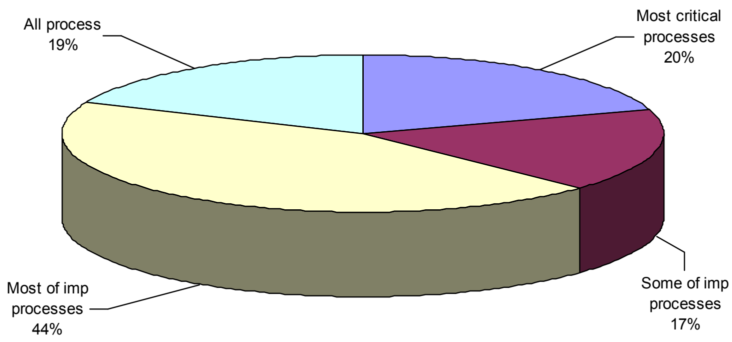

Figure 4.6 Coverage of new technology adoptions

From the above data, it is clear that sample consists of all types of companies ranging from technology leaders to laggards. The technology leader 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 exploit technology for competitive advantage. Such company readily adopts new technology on its availability and covers all processes for technological upgradation. Whereas the technology laggard company is weak and ill-prepared in all major areas of technology acquisition, use, development, strategy and so on. Such company rarely adopts new technologies to meet market requirements, and only when there is dire need, new technology is adopted meagerly for most critical processes. A major improvement programme is urgently needed to save such company from closure.

4.4 MANAGING NEW TECHNOLOGY ADOPTION

A few questions in questionnaire were designed to get an idea of the practices followed (ranging from very casually to highly systematic respectively on Likert scale of 1 to 4) by these companies for new technology adoption. Based on the responses from all the 70 companies, the average value (μ) and standard deviation (σ) were calculated. This score is plotted on a dot chart with companies on X axis and score on Y-axis as shown in figure 4.7 below. The middle line corresponds to the average score (μ) of all the companies, upper line indicates the value $\mu + \sigma$ and the lower line indicates the value $\mu - \sigma$. With the help of μ and σ, its company-wise status has been rated as follows:

Greater than ($\mu+\sigma$)	:	V. Good
Between μ and ($\mu+\sigma$)	:	Good

Between (μ-σ) and μ : Fair

Below (μ-σ) : Poor

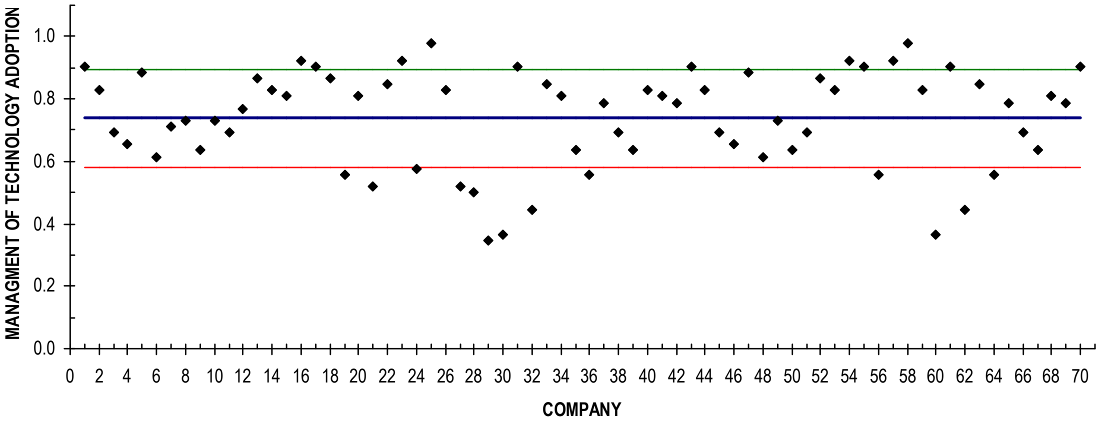

Figure 4.7 Management of new technology adoption

The dot chart in figure 4.7 shows these values against the companies getting it. The overall score of new technology adoption is good with average score of 73.75%. From this chart, it is clear that the status of technology adoption is good in about 35.7% of the companies, fair in 27.1% companies whereas 18.6% are in very good range and remaining 18.6% are in poor range. The survey indicated that the status of management of technology adoption is quite encouraging. Since all the respondent industries have been adopting the new technology depending upon their requirements or capabilities, the success of these companies varied a lot. There could be a vast difference between the management of new technology adoption from one company to another. The companies having very good score indicates that they have considered all aspects of technology adoption like availability of new technology, alternate processes, extensive analysis of trends, economic viability study, qualitative and quantitative analysis, consequential effects and manpower involvement. The poor bracket with 18.7% companies indicates that while adopting new technology, these companies get fascinated by its outlook and benefits, but do not go for its detailed analysis. There are a few companies in which the score of technology adoption is far below the average.

4.5 MANAGING TECHNOLOGY ADAPTATION

After a new technology is acquired by an organization, the implementation process requires more than communication of knowledge. The technology must be adapted to the organizational context and the relevant social and organizational processes, and routines may need to be adapted to the technology. The implementation of advanced technologies can be seen as a process of mutual adaptation of both, the technology and the environment, to each other. That is, the environment (the user, the organization and its norms, procedures, etc.) must be adjusted to accommodate the technology, and the technology must be reinvented or adapted to the environment. Inherently complex technologies, particularly those that affect the organization's core processes, require major social and organizational changes and resources. Thus, when there are high user interdependencies or a high knowledge burden, or if the technology is tightly bound to organizational processes, mutual adaptation is critical. It is observed through this survey that the score in management of technology adaptation is not as encouraging as in case of adoption. Based on this score in all the 70 companies, the average value (μ) and standard deviation (σ) has been calculated. This score is again plotted on a dot chart with companies on X axis and score on Y-axis, as shown in figure 4.8.

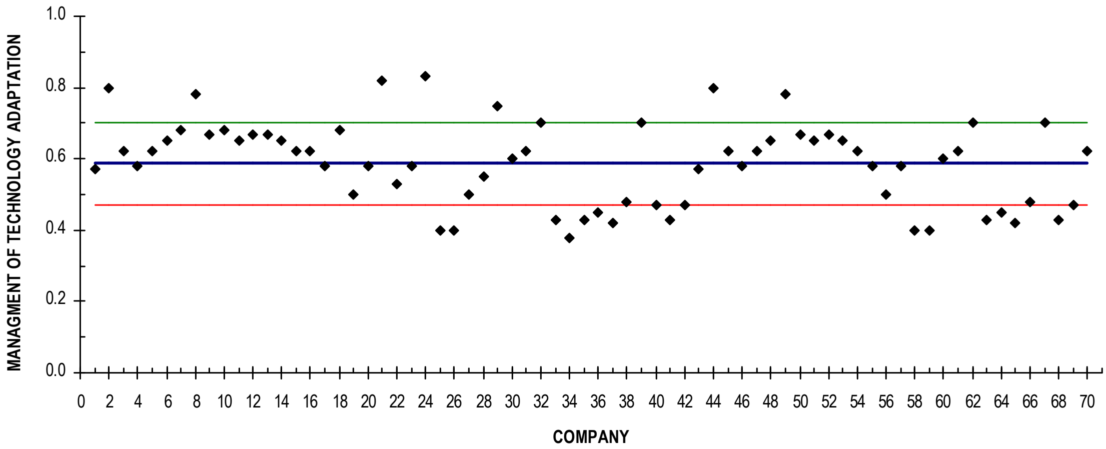

Figure 4.8 Management of technology adaptation

The overall score of new technology adaptation is just fair with average score of 58.75%. From this chart, it is clear that the status of technology adaptation is good in about 42.9% of the companies, fair in 22.8% companies whereas only 10% are in very good range and 24.3% are in poor range. The companies which have scored very good position shows that they have considered all aspects of technology adaptation like redesigning production system to achieve ergonomic and safe layout, standardization and smooth flow of material besides redesigning organizational structure and shifting, recruiting and training of people. The poor bracket with 18.7% companies indicates that while adapting new technology, these companies could not do well. Merely adopting new technology does not help in building technological capabilities; it requires adaptive efforts to be strengthened to make the adopted technology suitable for local conditions to yield higher results. There are still a few companies in which the score of technology adaptation is far below the average and these need attention.

4.6 FACTORS AFFECTING TECHNOLOGY ADOPTION:

Based on the review of literature and insights gained through discussions with experts, the following factors affecting the process of technology adoption have been identified. A code IP1 has been prefixed to each factor for ease of tabulation and statistical analyses.

- IP11: Role of government in technology adoption
- IP12: Impact of globalization on technology adoption
- IP13: Role of top management in technology adoption
- IP14: Manufacturing strategy and technology adoption policies
- IP15: Human factor

Section B13 of the questionnaire contained questions to assess the present status of these factors. Descriptive statistics of these responses are given as Appendix B.

4.6.1 IP11: Role of government in new technology adoption:

Manufacturing competitiveness is increasingly defined by skill, advanced technology, and high quality output. Policy-makers from governments, industrial development corporations, and international organizations, are recommending a shift away from labour-intensive manufacturing towards skill-intensive manufacturing, where high productivity and high value-added products provide competitive edge. Governments play a vital role in economy and industrialization in the country and may affect new technology adoption in three ways.

i. By encouraging the companies to adopt new technologies through their specialized agencies.
ii. By forcing adoption of new and cleaner technologies through its regulations on environment and pollution control.
iii. By providing incentive(s) for adoption in new technology such as through subsidies, tax holidays etc.

Responses to these sub-factors have been summarized in table 4.1.

Table 4.1 Item measures for role of government in technology adoption

S. No.	Item measures for role of government in technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Govt agencies' encouragement	11	16	24	19	191	68.21%
ii.	Govt regulations' (environmental related etc) compulsions	10	8	33	19	201	71.79%
iii.	Industrial policy incentives	6	18	18	28	208	74.29%

The above table showed that within the role of government, the contribution of each of these sub-factors is significant with the incentives having highest score. It is closely followed by the compulsions by the government regulations (on environment / pollution control etc) for adoption of cleaner technologies. The least score is with government agencies' encouragement for adopting new technologies. These three factors have been averaged to indicate the role of governments in new technology adoption for a particular company. This has been graphically shown in figure 4.9 with the middle line representing the average value.

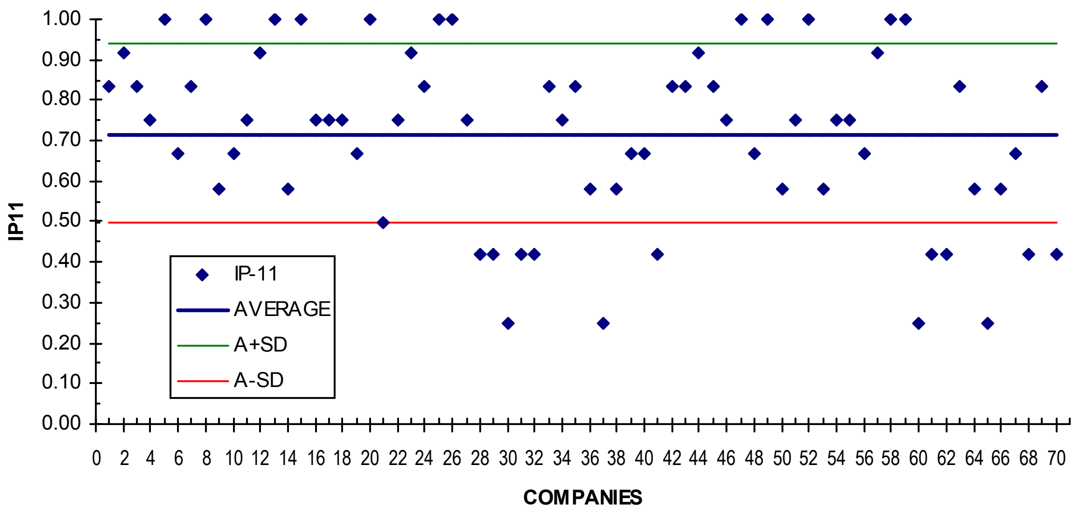

Figure 4.9 Status of role of government in new technology adoption

The overall role of governments in technology adoption is good with average score of 0.72. Amongst the respondents, 17.1% companies reported a very big role of governments in their technology adoption, 40% companies reported a fairly good role, 24.3% little role, and remaining 18.6% reported a negligible role.

4.6.2 IP12 Role of globalization in new technology adoption

Global export manufacturing is switching from labour-intensive, semi-skilled manufacturing to highly-skilled production and services. In the last few decades, the world economy has been undergoing an intense globalization process, resulting in a growing internationalization of the production and a highly competitive market. The new rules of competition imposed by increased globalization of markets and rapid technological changes are among the challenges which organizations must comply with. Competition is increasingly considered a war of movement. Static environments are giving way to continuously changing, dynamic environments. Firms' capabilities to anticipate and assess environmental demands in order to cope with these pressures and mobilize for change are becoming crucial. This tremendous increase in business globalization requires fast and efficient transfer of manufacturing technology around the world. The process is associated with a clear understanding of how well the new approach and technology can fit into the infrastructure of the new location or the host organization. Globalization has been the one of the important factor for adoption of new technology in Indian manufacturing industry, particularly after the new economic policy of Government of India since early 1990s. Globalization affects new technology adoption in three ways.

i. By creating opportunities in form of vast international markets and to manufacture the world class products.
ii. By creating threats in form of competition in local markets.
iii. By making easy availability of new / imported technologies.

Responses to these sub-factors have been summarized in table 4.2.

Table 4.2 Item measures for impact of globalization in new technology adoption

S. No.	Item measures for impact of globalization in new technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Opportunities created due to globalization in form of vast international markets	15	38	13	4	146	52.1%
ii.	Threats caused due to globalization in form of big competitors	23	25	10	12	151	53.9%
iii.	Availability of better technology	16	31	16	7	154	55.0%

The above table shows that with the impact of globalization, the contribution of all three sub-factors is almost same with the availability of better technology having a bit higher score, closely followed by threats due to intense competition. Responses to these three questions were averaged to assess the overall role of globalization in new technology adoption. These have been graphically shown in figure 4.10 with the middle line representing the average value.

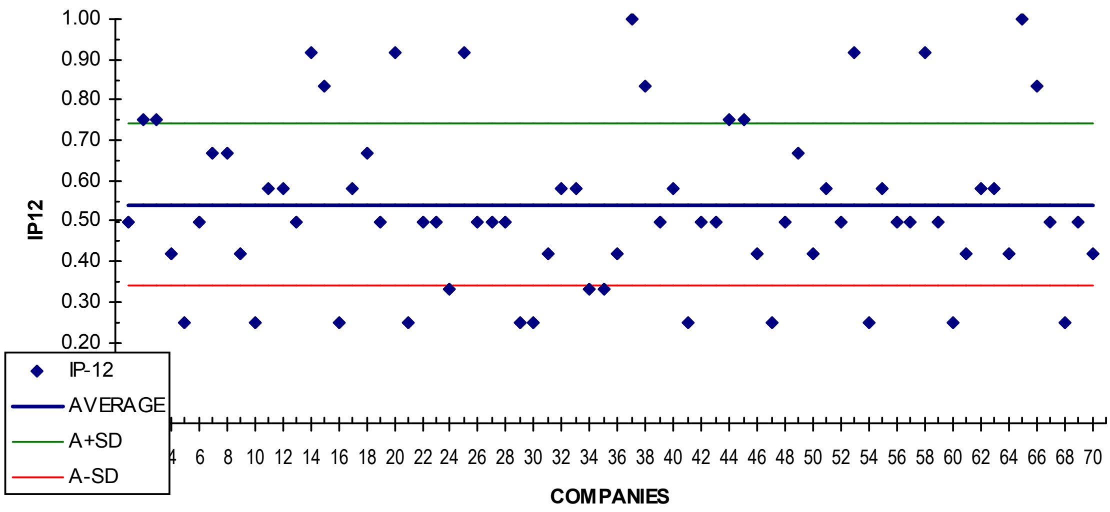

Figure 4.10 Status of impact of globalization on technology adoption

Responses show that the impact of globalization on technology adoption is not good in Indian manufacturing industries with average score of 0.54 only. Among the sample of respondents, the status of impact of globalization in 20% companies is in very good range, for another 20% companies in good range, 40% in fair and for remaining 20%, the status is poor. Figure depicts that there is no fixed trend for this factor, average is also low and the value of IP12 is broadly scattered.

4.6.3 IP13: Role of top management in technology adoption

Commitment from top management is a critical factor in any major organizational change. Top management must also be actively involved during the transition from old to new technologies. New technology brings about organization-wide changes. Such changes can have significant impact on the organization. Responsibility for new technology adoption planning should not be delegated away from top management. The perceived lack of support is as crippling to the implementation effort as a real lack of support. Thus, top management should explicitly demonstrate its support.

Top management must designate key personnel to oversee the new technology adoption process and allocate sufficient financial and other necessary resources for it. Since new technology adoption involves strategic and long-term decisions, top management should be broad-minded, and must be willing to take short-term risks for long-term gains. In evaluating the economic viability of new technology adoption, management is often reluctant to make any commitment unless there is a strong assurance that the investment can exceed the company's hurdle rate. Unfortunately, traditional justification methods such as the pay-back period, rate of return, and various discounted cash-flow analyses often fall short when a company is considering a major investment in new technology adoption. Many major benefits of new technology are either long-term or strategic in nature, and are often difficult to quantify. Thus, only a small part of the benefits can be taken into account by traditional justification methods.

Since top management takes and implements all new technology adoption related decisions, and this affects new technology adoption in three ways.

1. By supporting for new technology adoption
2. By being ready for taking short term risks in expectation of long term benefits.
3. By allocating sufficient financial resources.

Responses to these sub-factors have been summarized in table 4.3.

Table 4.3 Item measures for role of top management in technology adoption

S. No.	Item measures for role of top management in technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Top management support	1	0	27	42	250	89.3%
ii.	Top management readiness for short term risks	0	2	22	46	254	90.7%
iii.	Top management allocate proper funds	0	3	21	46	253	90.4%

Table 4.3 shows that within the role of top management, the contribution of all sub-factors is almost the same with the top management's readiness for short-term risk for long-term benefits having a bit higher score, closely followed by allocation of adequate funds by top management. Responses to these three questions were averaged to assess the overall role of top management in new technology adoption. This has been graphically shown in figure 4.11.

The overall role of top management in technology adoption is very good with average score of 0.90 and standard deviation of 0.12 only. Since the value average plus standard deviation exceeds 1.0, so very good status cannot be achieved statistically. For 57.1% companies, it is in good range, 24.3% in fair and for remaining 18.6%, the status is poor.

Figure depicts that average is very high and the value of IP13 is crowded in comparatively narrow range.

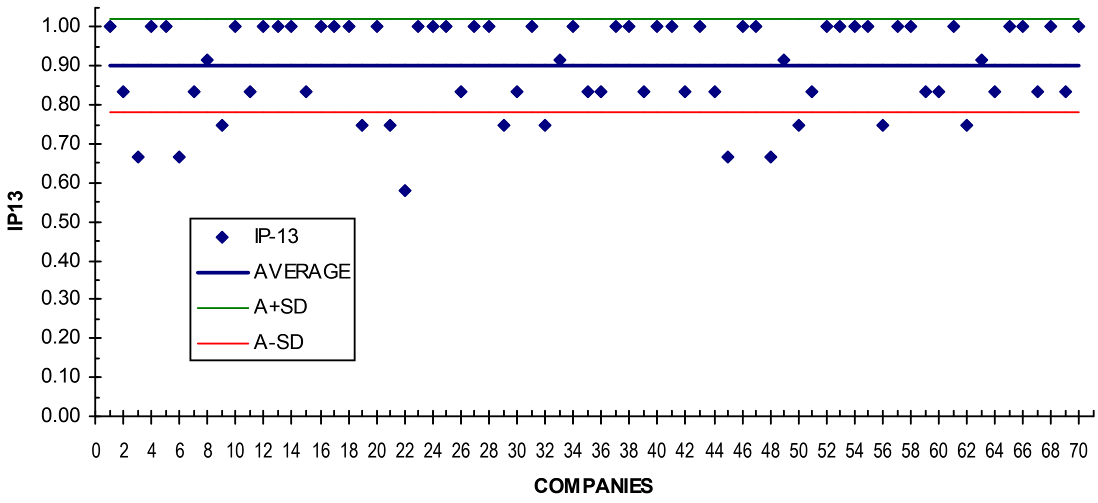

Figure 4.11 Status of role of top management in new technology adoption

4.6.4 IP14: Manufacturing strategy & technology adoption policies

A well thought manufacturing strategy can help a firm to make production technology choices that support its overall business objectives. Manufacturing strategies form a critical link not only in firms' ability to adopt new technologies, but also in their ability to shape their futures knowingly. The tendency for technological innovations to occur along defined trajectories is described in evolutionary economics literature as path dependence (Rosenburg, 1994). A path or trajectory denotes the trade offs, firms make relative to the available opportunities for technological advancement. The role of technology adoption policies is also included here. Insights were gained regarding existence and usage of these technology adoption policies. Data were also collected on updation / review of technology adoption policies and also on tracking of technology adoption costs. Responses to such sub-factors have been summarized in table 4.4.

Table 4.4 Item measures for role of manufacturing strategy & technology adoption policies

S. No.	Item measures for role of manufacturing strategy & technology adoption policies	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Existence of a written formal Manufacturing Strategy to help in new technology adoption.	6	10	41	13	201	71.8%
ii.	Proper understanding of current operations.	0	12	41	17	215	76.8%
iii.	Understanding of benefits of new	0	9	39	22	223	79.6%

	technology.						
iv.	The presence of well defined objectives of new technology.	0	9	36	25	226	80.7%
v.	Presence of well laid technology adoption policies.	1	21	46	2	189	67.5%
vi.	Extensive and thorough use of these technology adoption policies	1	29	34	6	185	66.1%
vii.	The adoption policies include training of the employees at all levels.	1	21	39	9	196	70.0%
viii.	The adoption policies include procedures and practices for capability building.	1	28	34	7	187	66.8%
ix.	Periodic updation and review of adoption policies.	1	27	37	5	186	66.4%
x.	Tracking of technology adoption costs.	2	30	34	4	180	64.3%
xi.	Help of adoption policies in capability building.	1	25	42	2	185	66.1%

Table 4.4 shows that within the factor 'manufacturing strategy and technology adoption polices', the contribution of all sub-factors is significant with the 'the presence of well defined objectives of new technology adoption' scoring the highest, closely followed by 'understanding benefits of new technology' and 'understanding of current operations'. The least scoring factors include 'help of such polices in capability building', 'extensive and thorough use of polices' and 'tracking of technology adoption costs'. Responses to these eleven sub-factors were averaged to assess the overall role of manufacturing strategy and technology adoption polices in new technology adoption. This has been graphically shown in figure 4.12 with the middle line representing the average value.

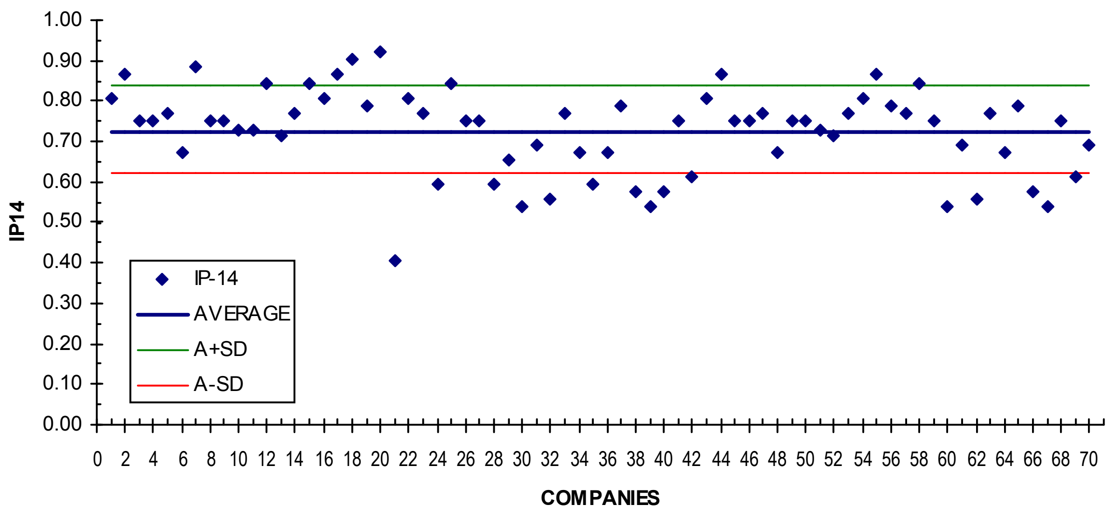

Figure 4.12 Status of role of manufacturing strategies and technology adoption policies

The overall role of manufacturing strategy and adoption policies in technology adoption is good with average score of 0.73 and standard deviation of 0.11 only. Among the respondents, the status of manufacturing strategy and technology adoption policies in 15.7% companies is very good range, for 47.1% companies it is quite good, in another 15.7% it is fair, and for remaining 21.4%, the status is poor. Figure depicts that 78.6% of the total respondents have the scores in range of fair to very good for this factor.

4.6.5 IP15: Human factor

The adoption of new technology is often accompanied by significant changes in human resource management because of several reasons. First, many new technologies require the substitution of capital for labor. Advanced manufacturing technologies at the factory floor can significantly reduce the demand for low-skilled and clerical workers. Second, new technologies can alter the work environment because they are integrative and information intensive. Third, these innovations empower workers by providing them with more information about activities in other functions areas. Last, new technology adoption stimulates an increase in demand for highly skilled or highly educated workers who may be more adept at learning the new technology.

Thus, the role of human factor through five sub-factors, such as in-house availability of technical expertise, training and attitude of employees etc was measured through questionnaire.

Responses to sub-factors concerning human factor have been summarized in table 4.5.

Table 4.5 Item measures for role of human factor in technology adoption

S. No.	Item measures for role of human factor in technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Involvement of manpower.	8	15	23	24	203	72.5%
ii.	Active participation from in-house engineers.	0	3	38	29	236	84.3%
iii.	Availability of Professional Consultants.	0	4	40	26	232	82.9%
iv.	Aligning the attitude of employees towards objectives of new technology adoption.	0	5	22	43	248	88.6%
v.	Formal Education and training programmes to include all classes of users ranging from top management to shop floor controllers.	0	3	16	51	258	92.1%

The above table shows that the human factor is highest scoring among all other factors affecting technology adoption. Within this, human factor, all the sub-factors score very high and are significant with the 'formal education and training programmes' scoring the highest, closely followed by 'attitude of employees towards new technology adoption' and 'active participation from in-house engineers'. The least scoring factors, but still with very good score of 72.5% is the involvement of manpower in new technology adoption. Responses to these sub-factors were averaged to assess the overall role of human factor in new technology adoption. This has been graphically shown in figure 4.13 with the middle line representing the average value.

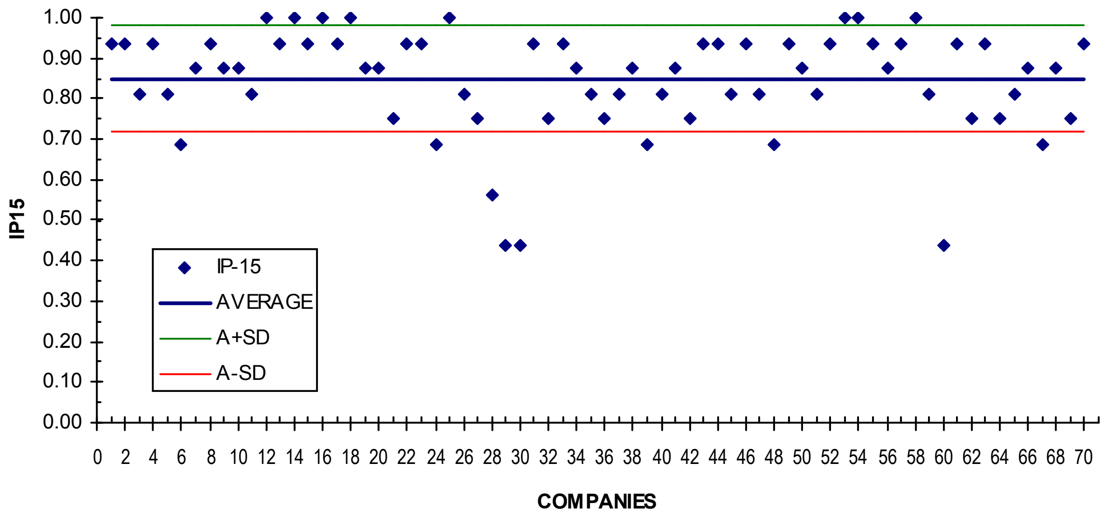

Figure 4.13 Status of role of human factor in new technology adoption

The overall role of human factor in technology adoption is very good with average score of 0.85 and standard deviation of 0.13 only. Among all respondents, role of human factor in 11.4% companies is very significant; for 47.1% companies, it is a major factor; in another 28.6%, a fairly good factor and for remaining 12.9%, its role is poor. Figure depicts that 87.1% of the total respondents have this factor in range of fair to very good.

4.7 FACTORS AFFECTING TECHNOLOGY ADAPTATION

Based on the review of literature and insights gained through discussions with experts, the following factors affecting the process of technology adaptation have been identified. A code IP2 has been prefixed to each factor for ease of tabulation and statistical analyses.

- IP21: Role of Government in technology adaptation
- IP22: Role of top Management in Technology Adaptation
- IP23: Employees' Education
- IP24: In-house R&D
- IP25: Adaptation Policies

Section C4 of the questionnaire contained questions to assess the present status of these factors. Descriptive statistics of these responses are also included in Appendix B.

4.7.1 IP 21: Role of government in technology adaptation:

The government through its control & initiatives may support the manufacturing industries in the process of technology adaptation. The present status of role of government in technology adaptation is summarized in table 4.6.

Table 4.6 Item measure for role of government in technology adaptation

S. No.		Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Role of Govt. in technology adaptation	19	39	8	4	137	48.9%

The survey indicated that the role of government here is not sufficient and the average score is merely 48.9%. This could be one of the reasons for lack of proper technology adaptations in India. This has been graphically shown in figure 4.14 with the middle line representing the average value.

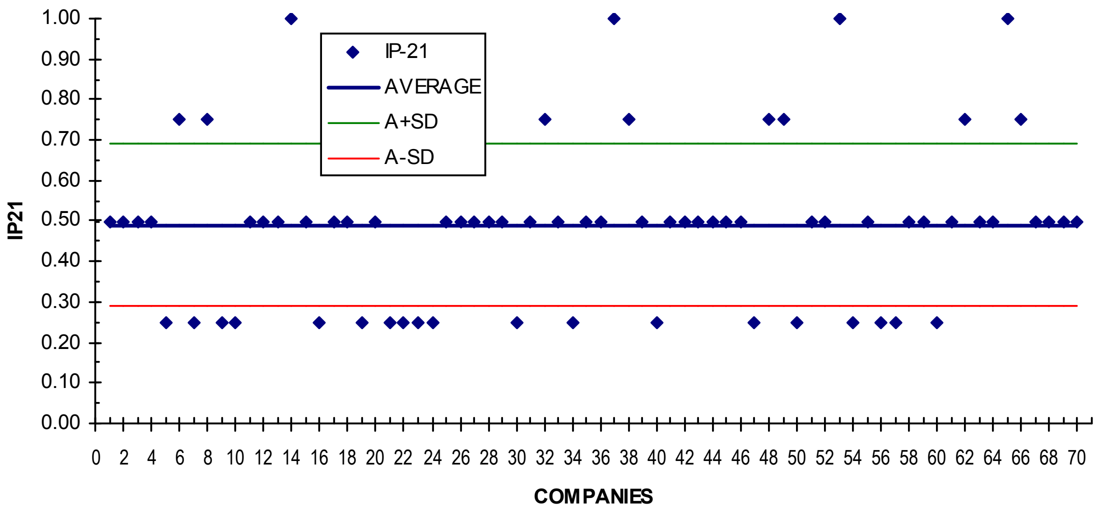

Figure 4.14 Status of role of government in technology adaptation

Figure 4.14 indicates that though the average score of role of government in technology adaptation is quite low, but still in 17.1 % companies, its status is very good. It may be due to a few public sector companies in the sample, and the role of government is very encouraging for these companies. Further the status of role of government in technology adaptation in 55.7% companies is between fair and good range, whereas for remaining 27.1% companies, the status is poor.

4.7.2 IP22: Role of top management in technology adaptation

Since adaptation also require the approval of top management, the role of top management affects the process of technology management in three ways:

i. By supporting for new technology adoption

ii. By being ready for taking short term risks in expectation of long term benefits.

iii. By allocating sufficient financial resources.

Responses to these sub-factors have been summarized in table 4.7.

Table 4.7 Item measures for role of top management in technology adaptation

S. No.	Item measures for role of top management in technology adaptation	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Top management support for technology adaptation.	0	0	26	44	254	90.7%
ii.	Readiness of Top management for short term risks.	0	4	19	47	253	90.4%
iii.	Allocation of proper funds by Top management for new technology adaptation.	0	2	20	48	256	91.4%

Table 4.7 shows that within the role of top management, the contribution of all sub-factors is almost same with the allocation of adequate funds by top management having a bit higher score, closely followed by support of top management for technology adaptation. Responses to these sub-factors were averaged to assess the overall role of top management in new technology adaptation, as shown in figure 4.15.

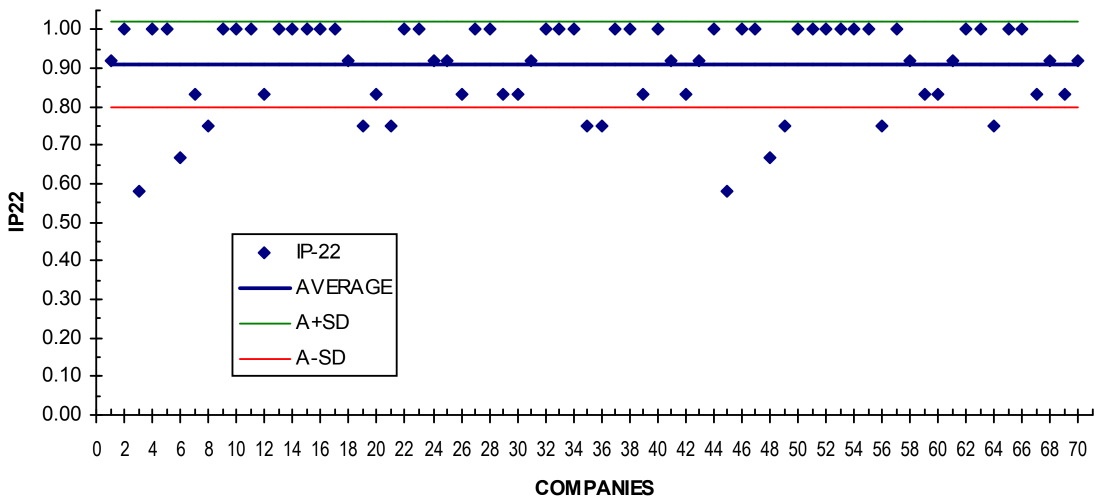

Figure 4.15 Status of role of top management in technology adaptation

The overall role of top management in technology adaptation is very good with average score of 0.91 and standard deviation of 0.11 only. Since the value average plus standard deviation exceeds 1.0, so the very good status cannot be achieved statistically, still for 65.8% companies, it is in good range, 17.1% in fair and for remaining 17.1%, the status is poor. Figure 4.15 depicts that there is a nearly fixed pattern for this factor, average is very high and the value of IP22 is crowded in narrow range. But here the matter demands concern when there are some companies, where the top management does not realize the importance of technology adaptation.

4.7.3 IP23: Employees' skill, education and attitude

The skill, education and attitude of employees are assumed to be important factors for technology adaptation. The present status of these factors is summarized in table 4.8.

Table 4.8 Item measures for role of employees' skill, education and attitude

S. No.	Item measures for role of employees' skill, education and attitude	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Skilled workers help in easy adaptation as compared to unskilled.	0	5	42	23	228	81.4%
ii.	Total number of engineers and technicians in the company is a key factor responsible for technology adaptation.	0	14	44	12	208	74.3%
iii.	Employees' willingness to accept changes (attitude).	0	11	38	21	220	78.6%
iv.	Existing staffing flexibility and production flexibility.	0	11	44	15	214	76.4%

Table 4.8 shows that role of employees' skill, education and attitude is significant. The skill of employees has highest score which is followed by employees' attitude or willingness to change. All above sub-factors have been averaged to find the aggregate status of this factor. This is graphically shown in figure 4.16.

The overall role of employee skill, education and attitude in technology adaptation is good with average score of 0.79 and standard deviation of 0.09 only. The low value of standard deviation indicates that there is less variation among the respondents regarding this factor. In 12.9% companies the status of this factor is very good; for 47.1% companies, it is in good range; 28.6% in fair and for remaining 11.4%, the status is poor. Figure depicts that there is a fixed trend for this factor, average is high and the value of IP12 is in narrow range around the average

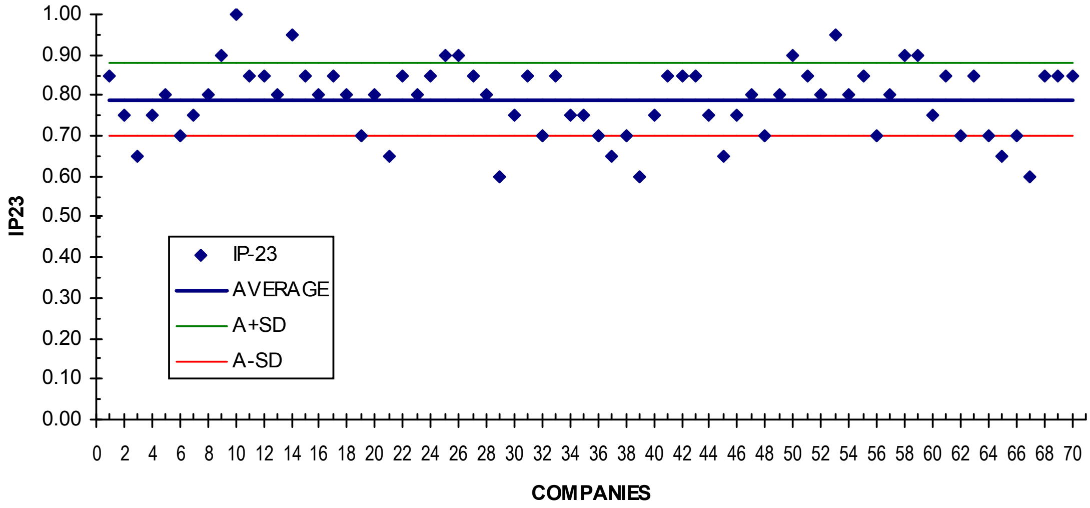

Figure 4.16 Status of role of Employees' Skill, Education and Attitude

4.7.4 IP24: In-house R&D

This is another factor, which is considered important on the basis of literature for technology adaptation. This factor has been measured through the questionnaire on the basis of only one question and its responses has been summarized in table 4.9.

Table 4.9 Item measure for role of In-house R&D in technology adaptation

S. No.	Item measure for role of In-house R&D in technology adaptation	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Importance of in-house R&D for technology adaptation.	0	12	48	10	208	74.3%

The graph in figure 4.17 has been plotted for this single sub-factor.

Figure 4.17 indicates that the average value is good (0.74) but standard deviation is comparatively larger at 0.14. Among the respondents, for 14.3% companies, its status is very good and for another 68.6% companies, it is good. So among all the respondents, 82.9% companies have the status of this factor in range of good to very good. In remaining 17.1% companies, its status is poor.

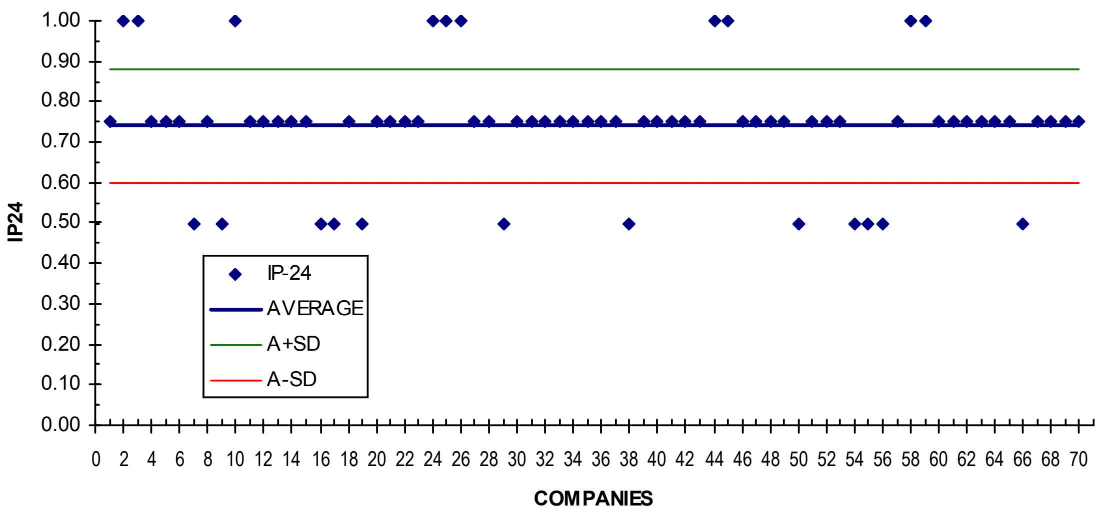

Figure 4.17 Status of role of In-house R&D in technology adaptation

4.7.5 IP25: Adaptation policies

The role of technology adaptation policies is also studied in this research work. Insights were gained regarding existence and usage of these technology adaptation policies. Data has also been collected on their updation or review and also regarding tracking of technology adaptation costs. The present status of these sub-factors have been summarized in table 4.10.

Table 4. 10 Item measures for role of technology adaptation policies in technology adaptation

S. No.	Item measures for role of technology adaptation policies in technology adaptation	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Presence of well laid technology adaptation policies.	1	50	13	6	164	58.6%
ii.	Extensive and thorough use of these policies	2	40	21	7	173	61.8%
iii.	The adaptation policies include training of the employees at all levels.	1	37	21	11	182	65.0%
iv.	The adaptation policies include procedures and practices.	2	36	23	9	179	63.9%
v.	Recording of adaptation information in equipment history	1	44	20	5	169	60.4%
vi.	Periodic updation and review of adoption policies.	1	47	18	4	165	58.9%
vii.	Help of adoption policies in capability building.	1	39	21	9	178	63.6%

Table 4.10 shows that within the adaptation policies, the scores of various factors are in range of 58.6% to 65%. The highest score is awarded to training of employees at all levels followed by adaptation policies to include procedure and practices for smooth

adaptation of new technologies. Responses to these sub-factors were averaged to assess the overall role of adaptation policies in new technology adoption. This has been graphically shown in figure 4.18 with the middle line representing the average value.

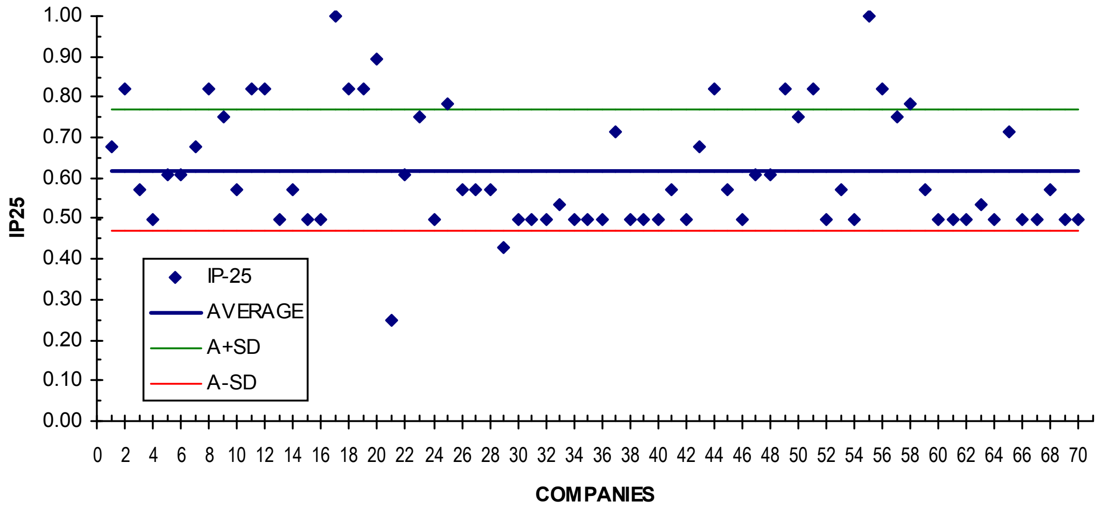

Figure 4.18 Status of role of technology adaptation policies in technology adaptation

The overall role of adaptation policies in technology adaptation is moderate with average score of 0.62 but at the same time it has the largest standard deviation of 0.15. Among the sample of respondents, the status of role of adaptation policies in 21.4% companies is in very good range, for 12.9% companies in good range, another 62.9% in fair and for remaining 2.9%, the status is poor. Figure depicts that 97.1% of the total respondents have this factor in range of fair to very good.

4.8 STATUS OF TECHNOLOGICAL CAPABILITY

Technological capabilities can be seen as all those abilities needed to carry out production related activities, ranging from planning, the purchasing of equipment, plant start-up and operation, the adaptation of inputs, improvements to production processes, changes to product specifications, product-process interface engineering (e.g. design-for-manufacture), incremental improvements to processes and products, new product design, basic research and applied R&D. The sources of technological learning and capability are many, involving both formal and informal processes. Formal sources include apprenticeships, plant investment and operation, training, applied engineering and R&D investments. Informal sources include negotiation with suppliers, communication between engineering team members, learning-by-observing experts, conversations and informal meetings. The technological capability, which refers to the firm's knowledge and capacity embedded into the individual and organizational resources, is one of the most important potentials for firms to gain the sustainable competitive advantage and high benefit return. With the enhancement of technological capability, the firms gain the sustainable economic return in the long time.

These capabilities need to be built up at three strategic levels for a developing country to acquire technology effectively: (a) the nation; (b) the sector; and (c) the firm or business enterprise. The technological capability at national level and sector level are beyond the scope of this research work, so here only the firm level technological capability has been discussed. The crucial capability for less developed countries is the managerial/strategic capability needed to adopt, implement and adapt specific technologies. With this strategic capability in place, it is far more likely that specific technologies can be acquired and developed successfully. By contrast, even if the company has specific hard technology resources, if the techno-managerial capabilities are weak or absent, then the company will, in all probability, not be able to develop the strategies needed to absorb and exploit the specific technologies in a way which fosters economic development.

Questions in the questionnaire related to technological capability used have been adopted from Bessant *et al*. (2000). These self assessment questions are based on nine sub-dimensions of technological capability. This scoring system, first help to assess the current status of technological capability of a company and then secondly, help to identify the strengths and weaknesses of the company according to nine sub-dimensions. Responses to these questions have been summarized in table 4.11.

Table 4.11 Item measures for technological capabilities (Self-assessment Technological Capability Audit Tool)

S. No.	Item measures for technological capabilities	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Is your company well aware of the technologies most important to its business?	0	8	40	22	224	80.0%
ii.	Does technology play an important part in your company's business strategy?	0	10	44	16	216	77.1%
iii.	Is your company well equipped to assess technological opportunities?	1	13	37	19	214	76.4%
iv.	Can your company assess technology threats without difficulty?	0	18	39	13	205	73.2%
v.	Does your company have special technological strengths which it is able to	0	20	35	15	205	73.2%

S. No.	Item measures for technological capabilities	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
	exploit?						
vi.	Does your company know which technologies to outsource and which to develop internally?	0	10	42	18	218	77.9%
vii.	Is your management skilled at formulating a technology strategy to meet business goals?	2	15	27	26	217	77.5%
viii.	Does your company know its main technology priorities?	1	9	23	37	236	84.3%
ix.	Does your company have a well developed technology 'vision'?	0	13	32	25	222	79.3%
x.	Does your company know how to select the technology needed for its business?	0	10	19	41	241	86.1%
xi.	Does your company know the best sources of technology?	1	9	30	30	229	81.8%
xii.	Is your company effective at acquiring technology from external sources?	1	10	39	20	218	77.9%
xiii.	Does your company have good links with important external suppliers of technology?	0	14	33	23	219	78.2%
xiv.	Are your technology activities (e.g. engineering and R&D) organized effectively within company?	3	15	34	18	207	73.9%
xv.	Do you have clear processes for carrying out technology projects?	3	12	25	30	222	79.3%
xvi.	Does your company have a good system for assessing technology projects?	2	4	39	25	227	81.1%
xvii.	Does your company carries out post-project reviews?	0	16	29	25	219	78.2%
xviii.	Are you able to learn from one technology project to another?	1	10	39	20	218	77.9%
xix.	Do Government policies encourage you to invest in technology?	18	32	7	13	155	55.4%
xx.	Do you use external organizations (e.g. consultancy firms) to assist you with technology assessment?	6	23	26	15	190	67.9%
xxi.	Do you use outside bodies to help you develop technology?	13	26	22	9	167	59.6%
xxii.	Do the external organizations help you in implementing your technology strategy?	15	29	14	12	163	58.2%
xxiii.	Do you work with universities in key technology projects?	35	25	5	5	120	42.9%
xxiv.	Do you work with government research institutes in important technology projects?	26	27	12	5	136	48.6%

Table 4.11 indicates that the average score of five questions is greater than 80% whereas only two questions have score less than 50%. It has been found that the interaction of company with university and government research institutes is very low and this is an area where a lot has to be done to strengthen the technological capabilities.

It is also helpful to define capability according to nine constituent components as discussed briefly below and their average values graphically represented in figure 4.19.

1. ***Awareness***: being aware of technology issues and the need to acquire technologies. Questions i, viii and xix collectively indicate the status of awareness in the company. The average score of awareness has been found to be 73.2%.
2. ***Search***: the ability to seek out and identify technologies to solve particular problems. Questions vi and xi collectively indicate the status of search in the company. The average score of search has been found to be 79.8%.
3. ***Core capability***: the building of a distinctive capability in some area of technology. Questions v, xiv and xv collectively indicate the status of core capability in the company. The average score of core capability has been found to be 75.5%.
4. ***Strategy***: the development of a technology strategy, including a framework with priorities and an action plan. Questions ii, vii and ix collectively indicate the status of strategy in the company. The average score of strategy has been found to be 78.0%.
5. ***Assess and select***: the ability to assess and select cost effective technology solutions. Questions iii, iv and x collectively indicate the status of assess and select in the company. The average score of assess and select has been found to be 78.6%.
6. ***Acquire***: the acquisition and absorption of specific technologies. The question xii indicate the status of acquire in the company. The average score of acquire has been found to be 77.9%.
7. ***Implement***: the skill involved in making effective use of technology. The question xxii indicate the status of implementation in the company. The average score of implement has been found to be 58.2% which is quite low as compared to other sub-dimensions.
8. ***Learn***: the ability to learn from and accumulate experience in order to continuously improve capabilities. Questions xvi, xvii and xviii collectively

indicate the status of learn in the company. The average score of learn has been found to be 79.0%.

9. ***Linkage***: the ability to form and exploit linkages with networks of technology suppliers and others involved in technology. Questions xiii, xx, xxi, xxiii and xxiv collectively indicate the status of linkage in the company. The average score of awareness has been found to be 59.4%.

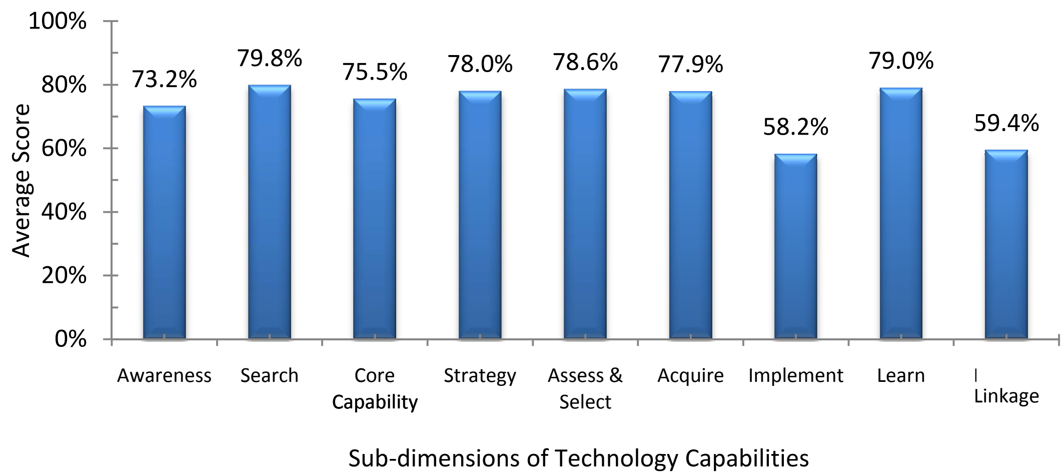

Figure 4.19 Status of sub-dimensions of technological capabilities

The company-wise score of this assessment tool categorize the companies to four levels of technological capabilities as discussed in table 4.12, where μ is average score of all these questions for all companies and σ the corresponding standard deviations.

Table 4.12 Technological capability score and audit reports

Level	Score	Technological Capability	Audit Report
1	Below (μ-σ)	Passive (poor)	The company is weak and ill-prepared in all major areas of technology acquisition, use, development, strategy and so on; a major improvement programme is urgently needed
2	Between (μ-σ) and μ	Reactive (fair)	The company has poorly developed capabilities in most areas of technology strategy, search, acquisition and capability building. However, there are some strengths upon which to build
3	Between μ and (μ+σ)	Strategic (good)	The company has strong in-house capabilities and takes a strategic approach to technology. In some areas, the firm is behind the international technology frontier but has many important strengths upon which to build
4	Above (μ+σ)	Creative (very good)	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.

Figure 4.20 indicates that the status of technological capability in 12.9% of industries is very good i.e. creative. These companies have a fully-developed set of technological capabilities and are able to help define the international technology frontier. In many areas it takes a creative and pro-active approach to exploit technology for competitive advantage. A fairly large number of the companies (44.3%) have a good status for technological capability. These companies have strong in-house capabilities and take a strategic approach to technology. In some areas, the firms are behind the international technology frontier but have much important strengths upon which to build.

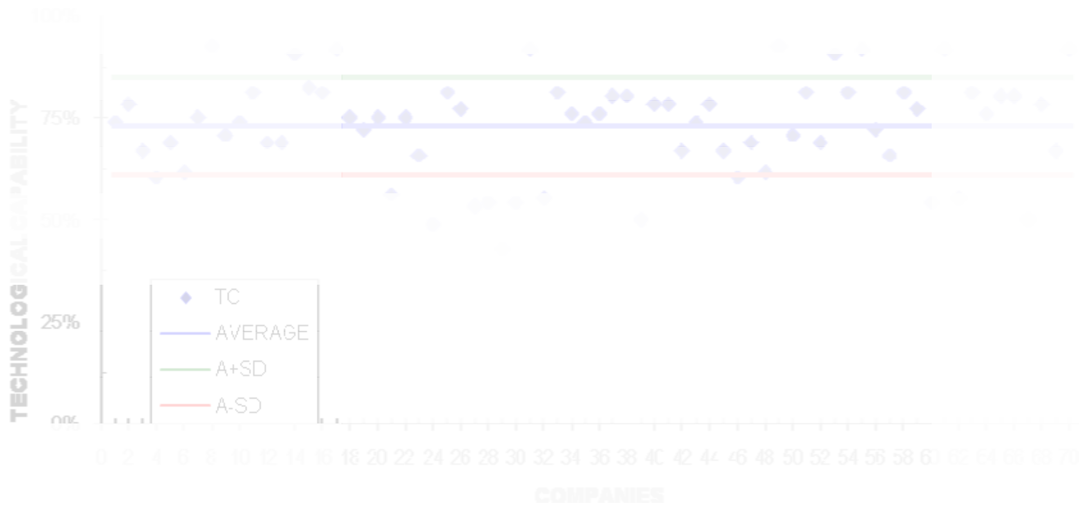

Figure 4.20 Status of technological capabilities

In 24.3% companies, the status of technological capability is fair. These companies have poorly developed capabilities in most areas of technology strategy, search, acquisition and capability building. However, there are some strengths upon which to build. For the remaining 18.6% companies, their technological capability is in a poor state. These companies are weak and ill-prepared in all major areas of technology acquisition, use, development, strategy and so on; a major improvement programme is urgently needed.

4.9 SUCCESS DUE TO NEW TECHNOLOGY IMPLEMENTATION

The companies implement new technologies / advanced manufacturing technologies to obtain certain specified benefits. It has also been assumed that there would be some hierarchy among those benefits that a company considers to be important. While one company might consider improving profits as its most important objective another company may place more emphasis on reductions in manufacturing lead times. If this is indeed the case, it would be more reasonable to assume that a company will assess the success of a technology by first considering the extent to which the technology has been able to produce those benefits for which it was adopted. Unplanned positive outcomes that can be traced to the implementation of the technologies can then be viewed as unexpected positive benefits. AMT implementations have been credited with the ability to offer an even more extensive range of benefits which have been classified by various authors as: manufacturing, non-manufacturing, strategic, tactical, technical, intangible and general benefits.

In practice, however, companies appear to be judging the success of their systems on the achievement of a few important benefits. It has been found that many of the companies that reported successful implementation of AMT were not exploiting the full benefits offered by these systems. Given the fact that even companies within the same industry emphasize different corporate strategies, and corporate and marketing objectives it is expected and understandable that individual companies that adopt the same type of AMT may emphasize different benefits. Yet many empirical studies assess the performance of AMT adopting companies on the basis of the achievement of a few performance objectives such as improved market share, improved flexibility, and increasing return on assets without first assessing whether these objectives were the most important considerations for the companies. Hence, adoption of AMT can bestow, not only operational benefits, but marketing and strategic benefits as well. However, each technology offers its own basket of differentiated operational, strategic and marketing capabilities. It should be noted that the above benefits/ objectives are not, and should not be interpreted as being mutually exclusive. For example, reductions in set-up times should lead to reduced manufacturing lead times and ultimately to shortened delivery lead times.

In this study 12 benefits that represent the most common objectives for adopting new technology have been investigated. The list of benefits/objectives and their present status have been summarized in table 4.13.

Table 4. 13 Item measures for success due to new technology

S. No.	Item measures for success due to new technology	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Increased ability to change production lot sizes;	2	25	31	12	193	68.9%

ii.	Increased variety of part-types or products manufactured;	5	18	34	13	192	68.6%
iii.	Increased average number of tasks performed by an operator;	1	12	38	19	215	76.8%
iv.	Increased operator output rates;	6	6	35	23	215	76.8%
v.	Increased plant revenues from manufacturing operations;	0	12	37	21	219	78.2%
vi.	Reduced delivery lead times;	7	13	32	18	198	70.7%
vii.	Reduced overhead costs;	3	17	26	24	211	75.4%
viii.	Improved product quality;	0	10	27	33	233	83.2%
ix.	Increased inventory turnover rates;	3	13	34	20	211	75.4%
x.	Reduced production change-over times;	3	17	30	20	204	72.9%
xi.	Reduced time needed for a major change in an existing product;	6	21	26	17	189	67.5%
xii.	Reduced time-to-market for a new product	3	12	36	19	208	74.3%

Table 4.13 indicates that all the benefits have good scores in the range of 67.5% to 83.2%. The maximum benefit derived from new technology among the respondent companies is regarding 'improved product quality' with score of 83.2%. So the adoption of new technology leads to improved product quality in most of the companies. It is then followed by 'increased revenue from manufacturing' with average score of 78.2%. The next rank is scored at 76.8% by two benefits i.e. 'increased average number of tasks performed by an operator' and 'increased operator output rates'. These indicate increased productivity. The benefit 'reduced time for a major change in an existing product' though scored least among other listed benefits, but still has a good score 67.5%.

Responses to these twelve benefits were averaged to assess the overall status of success due to new technology. This has been graphically shown in figure 4.21.

Figure 4.21 shows that the status of success due to new technology is very good in 17.1% companies. The success is good for another 40% companies and fair for 20% companies. For remaining 21.4% companies the status of success is poor. On an average, this effort in India is quite encouraging as the average score in this case is 71%, but a closer look at graph in figure 4.21 shows that there are a few companies in which the score is much lower than the average. Those companies must analyze their process of technology adoption and adaptation.

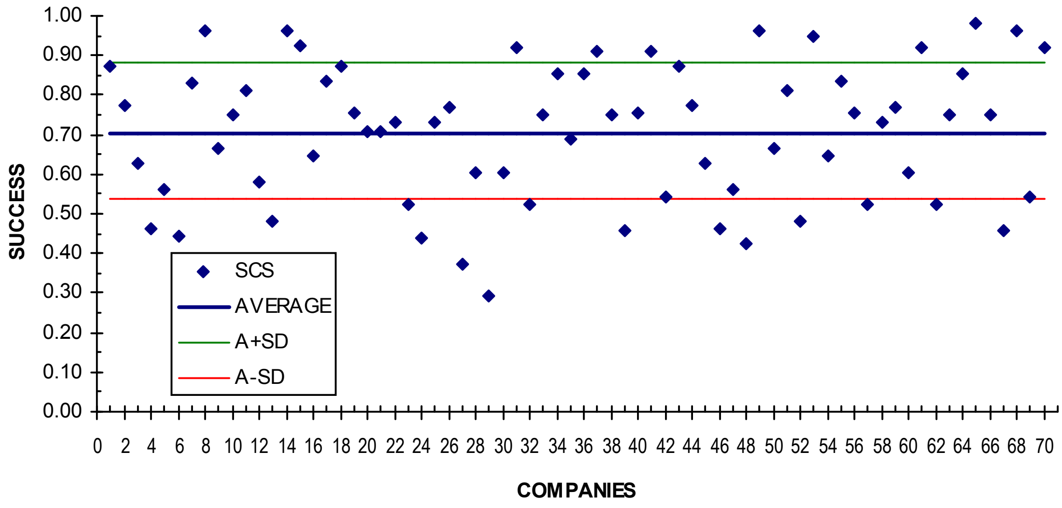

Figure 4.21 Status of success due to new technology

4.10 FLEXIBILITY

It has been discussed in earlier chapters and then referred by literature review, that introduction of flexibility in the management of technology adoption and adaptation certainly shows encouraging results. These results have been derived from the survey scores in particular questions related to flexibility in technology adoption and adaptation, and other questions related indirectly to the flexible management process. As flexibility is an integral approach to technology adoption, technology adaptation and technological capability building, the questions related to flexibility were not listed separately in the questionnaire, but the scores of these questions have been analyzed and presented in this section.

4.10.1 Flexibility in technology adoption

The present level of flexibility in technology adoption has been shown in figure 4.22, which indicates a large variation in present status of flexibility in technology adoption with a moderate average score of 68.7% only. The flexibility comes out to be in wide range of 25% to 100% on the basis of questions used in survey. 15.7% companies are highly flexible in technology adoption, which indicates that these companies are fully equipped with various modern manufacturing practices. In 42.9% companies, there is good flexibility in technology adoption, whereas in 25.7% companies, flexibility in technology adoption is fair. On the other hand, around 15.7% companies fall in poor bracket. These companies still have old type of management system which is very rigidand bringing any change there, is a challenging task.

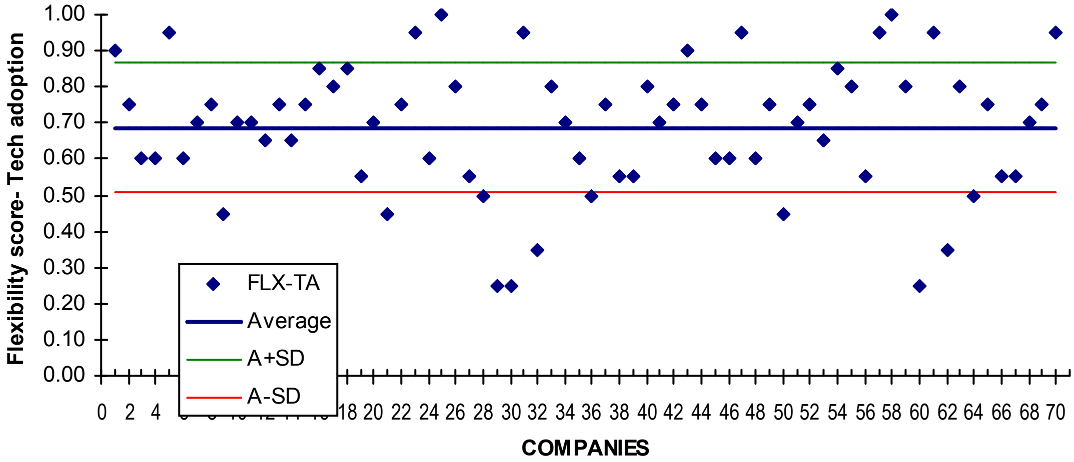

Figure 4.22 Status of flexibility in technology adoption

4.10.2 Flexibility in technology adaptation

The present level of flexibility in technology adaptation has been graphically shown in figure 4.23. The flexibility comes out to be in a narrow range of 46% to 87% with an average score of 70.8%. In 20% companies, there is high flexibility in technology adaptation, which indicates that these companies are fully equipped with various modern manufacturing practices and their process of technology adaptation is so flexible that they do not need much of the redesigning in production systems like layouts, standardization, and in even shifting, recruiting or training of personnel required. In 34.3% companies, there is good flexibility in technology adaptation, whereas in 30% companies, flexibility in technology adaptation is just fair. On the other hand, around 15.7% companies fall in poor bracket, which again needs major overhaul of their system. These companies are hard core old fashion companies that are very rigid and any need of technology adaptation requires all existing systems to be uprooted and then redesigning the whole production systems. These companies also require recruiting, shifting and training of employees to a large extent and a lot of efforts and resources are needed to make new technology acceptable to their employees.

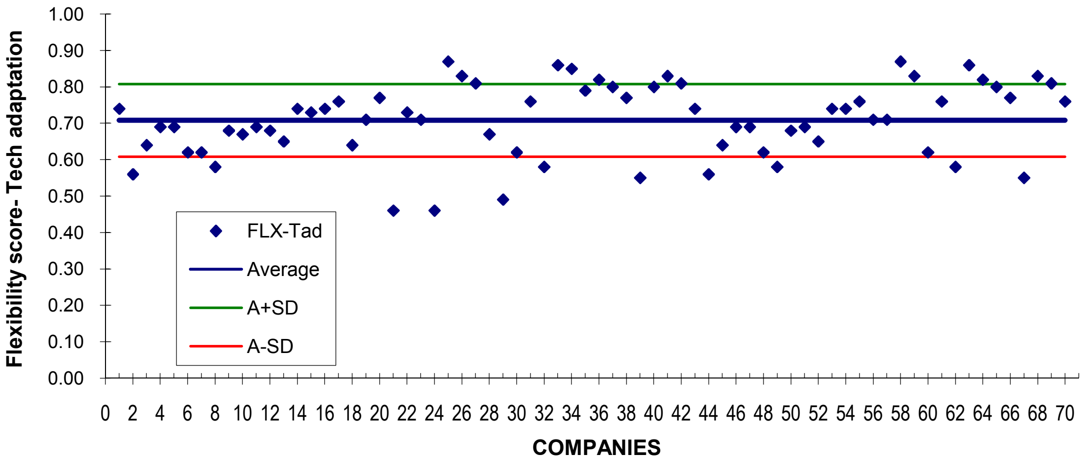

Figure 4.23 Status of flexibility in technology adaptation

4.10.3 Flexibility in technological capability

The present level of flexibility in technological capability has been graphically shown in figure 4.24.

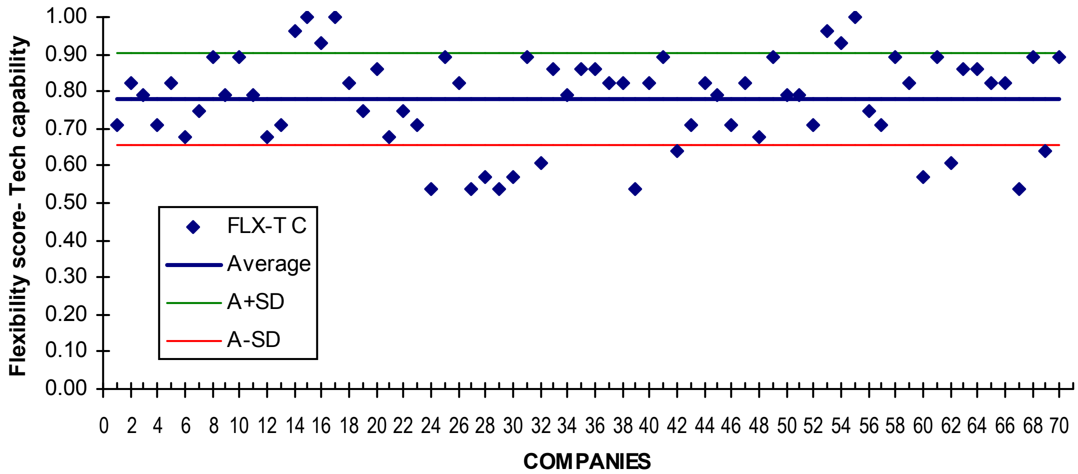

Figure 4.24 Status of flexibility in technological capability

Figure 4.24 indicates a moderate variation in present status of flexibility in technological capability with an average score of 77.9%, which is highest among all types of flexibilities under study. Here, the flexibility comes out to be in moderate range of 54% to 100%. In 10% companies, there is very high flexibility in technological capability. This indicates that these companies are fully equipped with the capabilities of handling technologies and their process of building technological capability is so flexible that they do not need much of the special efforts to develop these further. These are strong enough in all the nine sub-dimensions of technological capability, namely: Awareness, Search, Core capability, Strategy, Assess and select, Acquire, Implement, Learn and Linkage. In 50% companies, there is medium to high level of flexibility in technological capability whereas in 22.9% companies, flexibility in technological capability is medium. On the other hand, around 17.1% companies fall in poor bracket, with low flexibility in technological capability. These companies are hard core old fashion companies and are rigid with regard to building their technological capability. Building technological capability in these companies is a challenging task.

4.10.4 Overall flexibility

The present level of overall flexibility, which is the combination of flexibilities in technology adoption, technology adaptation and technological capability, has been graphically shown in figure 4.25.

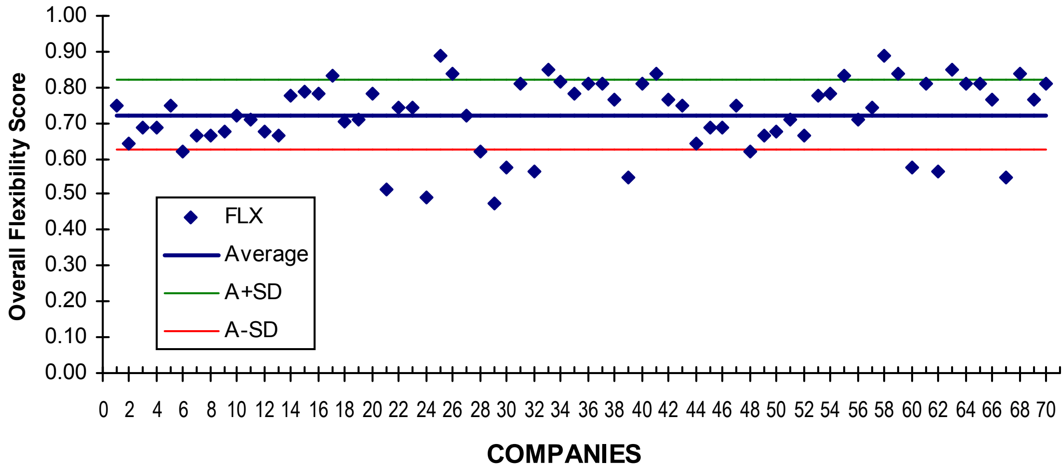

Figure 4.25 Status of overall flexibility

Figure 4.25 indicates a variation in present status of overall flexibility with an average score of 72.3%. The flexibility comes out to be in comparatively narrow range of 47.5% to 88.8% on the basis of questions used in survey. 14.3% companies have overall flexibility in very good position, which indicates that these companies are fully enjoying all the benefits of being flexible. These companies have all the systems flexible like, machines, layouts, material flow and even people, so they need not to put in extra ordinary efforts to bring changes in their systems. 38.6% companies have overall flexibility in good position whereas for 30% companies, the status is just fair. On the other hand, around 17.1% companies fall in poor bracket, which need full redesign of their whole system. These companies are unadventurously managed, are very rigid and have low technological capabilities. These require recruiting, shifting and training of employees to a large extent and a lot of efforts are to be put in to make new technology acceptable to employees.

The average score of flexibility in technology adoption, technology adaptation, technological capability and overall has been shown graphically in figure 4.26.

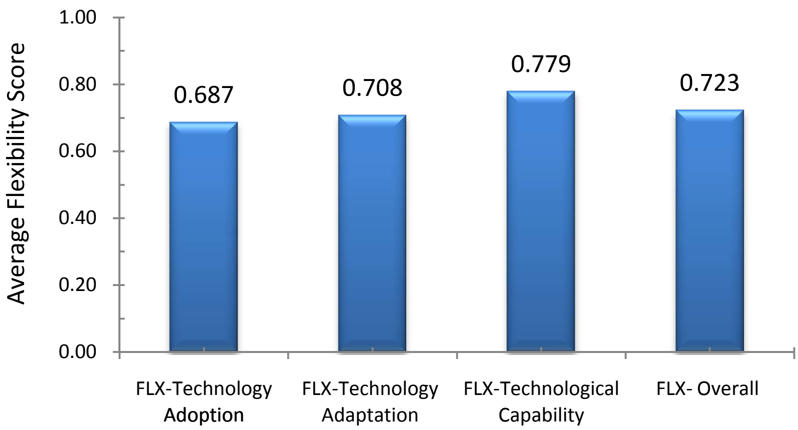

Figure 4.26 Average flexibility score

Graph in figure 4.27 represents the maximum values, minimum values and range of flexibility in technology adoption, technology adaptation, technological capabilities and overall flexibility.

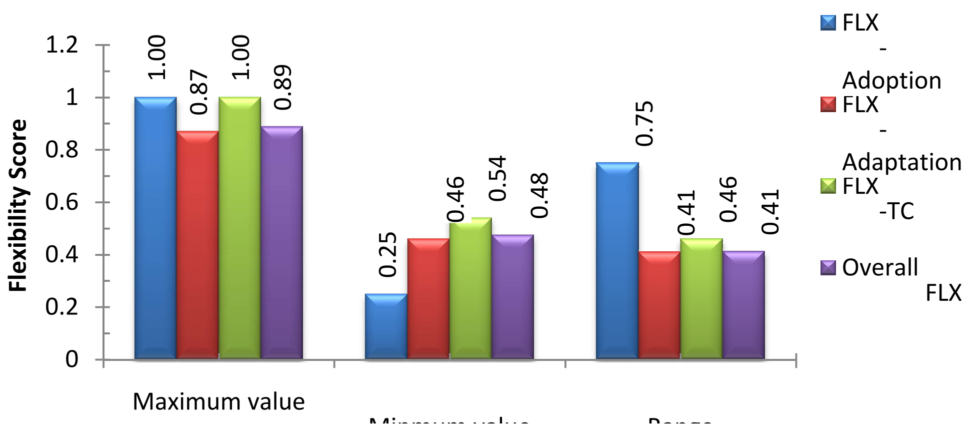

Figure 4.27 Flexibility Score (maximum, minimum and range)

4.11 EMPIRICAL ANALYSIS OF DATA

In empirical analysis, independent and dependent variables (constructs) have been formulated on the basis of literature review and the objectives/issues of this research. Five factors each affecting technology adoption and technology adaptation five factors affecting were identified as independent variables. The present status of technological capabilities, success due to implementation of technology adoption and adaptation; and flexibility were taken as dependent variables. The convergent and discriminant validities of the constructs and their measures were carried out and various statistical tools and techniques were employed using SPSS software to get 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 considered as an appropriate multivariate statistical technique to use (Hair *et al.*, 1998).

4.11.1 Validation of data

A study is valid if it measures what it claims to measure 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. Data collected through the survey were 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 constuct are correlated. The Cronbach's Alpha has been used to establish internal consistency validity i.e. the convergent validity, with 0.50 considered the acceptable value for exploratory study (Nunally, 1978). The reliability tests were carried out using SPSS software 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 table 4.14.

Table 4.14 List of item measures for independent variables

Independent Variables		Factors / Items included in variable	Cronbach's Alpha
Concerning Technology Adoption	IP11: Role of government in new technology adoption	1. Govt. through its agencies may encourage the companies to adopt new technologies 2. Govt. through its regulations (environment / pollutions regarding) may force adoption of new and cleaner technologies. 3. The Govt. may provide some incentive for adoption in new technology like subsidy, tax relaxations etc.	0.821
	IP12: Impact of globalization on new technology adoption	1. Globalization created opportunities in form of vast international markets and to manufacture the world class products, AMT is a must 2. Globalization created threats in form of big competitors in local markets and to compete with them, AMT adoption is a must. 3. The availability of AMT has been easier due to globalization and due to easy availability one might adopt AMT.	0.847
	IP13: Role of top management in technology adoption	1. Availability of top management support for new technology adoption 2. Readiness of the top management for taking short term risks for long term benefits, since new technology adoption decision may result in a lot of disruptions & risks in short term but in long run these are surely to	0.764

Independent Variables		Factors / Items included in variable	Cronbach's Alpha
		compensate the earlier risks. 3. Without the funds new technologies can never be adopted. The top management attitude towards fund allocation affects new technology adoptions.	
	IP14: Manufacturing strategy & technology adoption policies	1. A written formal Manufacturing Strategy 2. Proper understanding of current operations 3. Understanding of benefits of new technology 4. The presence of well defined objectives of new technology. 5. Cordial relationships with the suppliers of technology. 6. The selection of appropriate supplier of technology. 7. Well laid technology adoption policies. 8. Extensive and thorough use of these technology adoption policies 9. The adoption policies include training of the employees at all levels. 10. The adoption policies include procedures and practices for capability building of your plant 11. Adoption policies updated and reviewed periodically. 12. Tracking of technology adoption costs.	0.890
	IP15: Human factor	1. Involvement of employees in Technology Adoption 2. Active participation from in-house engineers 3. Aligning the attitude of employees towards objectives of new technology adoption 4. Formal Education and training programmes	0.666
Concerning Technology Adaptation	IP21: Role of Government in technology adaptation	1. The government through its control & initiates may support the manufacturing industries in the process of technology adaptation	- NA -
	IP22: Role of top management in technology adaptation	1. Extending support for technology adaptations 2. Readiness for taking short term risks for long term benefits, since new technology adaptation decisions may result in disruptions in work flow & risks. 3. Without the funds new technologies can never be adapted. The top management attitude towards fund allocation affects new technology adaptations.	0.790
	IP23: Employees' education	1. Overall higher education level of employees. 2. Skilled Labor. 3. Total number of engineers and technicians in the company. 4. Attitude of people in company to accept changes. 5. Staffing flexibility	0.628
	IP24: In-house R&D	1. Present status of in-house R&D.	- NA -
	IP25: Adaptation policies	1. Well laid technology adaptation policies. 2. Extensive and thorough use of these technology adaptation policies. 3. The adaptation policies include training ofemployees at all levels. 4. The adaptation policies include procedures and practices. 5. Records of adaptation information into equipment history 6. Adaptation policies updated and reviewed periodically. 7. Adaptation policies help in capability building.	0.932

Further table 4.15 has been delineated to summarize convergent validity of independent variables.

Table 4.15 Internal consistency and convergent validity of independent variables

Construct	No. of Items	Mean	Variance	Minimal item to total correlation	Cronbach's Alpha
IP11	03	2.86	0.75	0.84	0.821
IP12	03	2.15	0.67	0.85	0.847

IP13	03	3.60	0.22	0.75	0.764
IP14	13	2.90	0.18	0.42	0.890
IP15	04	3.39	0.27	0.62	0.666
IP21	01	1.96	0.62	1.0	- NA -
IP22	03	3.63	0.21	0.79	0.790
IP23	05	3.15	0.13	0.42	0.628
IP24	01	2.97	0.32	1.0	- NA -
IP25	07	2.47	0.35	0.76	0.932

Table 4.15 indicates that all the measures which have been clubbed to form independent variables have acceptable convergent validity. Similarly table 4.16 shows the corresponding values for dependent variables.

Table 4.16 List of item measures for dependent variables

Dependent Variables	Number of factors / items included in variable	Cronbach's Alpha
Technological capability	24	0.928
Success due to AMT implementation	12	0.882
Flexibility	31	0.901

Table 4.16 also indicates that all the measures which have been clubbed to form dependent variables have high degree of convergent validity.

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. 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).

A ten factor correlated model representing each of the ten elements has been used to examine discriminant validity. The within-group and between-group variances for all the constructs are shown in table 4.17. 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 table, the within-group variances of any two constructs exceed the variance between those two constructs, thereby supporting discriminant validity.

Table 4.17 Discriminant Validity Testing Matrix

	IP11	**IP12**	**IP13**	**IP14**	**IP15**	**IP21**	**IP22**	**IP23**	**IP24**	**IP25**
IP11	**0.745**	0.162	0.086	0.475	0.468	-0.215	-0.041	0.301	0.299	0.321

	IP11	IP12	IP13	IP14	IP15	IP21	IP22	IP23	IP24	IP25
IP12	0.114	**0.666**	0.072	0.368	0.351	0.649	0.060	-0.017	0.178	0.414
IP13	0.035	0.027	**0.217**	0.248	0.420	0.086	0.561	0.386	-0.025	0.097
IP14	0.173	0.127	0.049	**0.178**	0.669	0.001	0.198	0.412	0.020	0.700
IP15	0.210	0.149	0.102	0.147	**0.271**	0.085	0.347	0.474	-0.011	0.380
IP21	-0.146	0.417	0.031	0.000	0.035	**0.621**	-0.017	-0.110	0.095	0.049
IP22	-0.016	0.022	0.119	0.038	0.082	-0.006	**0.207**	0.417	-0.173	0.074
IP23	0.092	-0.005	0.064	0.062	0.088	-0.031	0.067	**0.126**	0.167	0.243
IP24	0.146	0.082	-0.007	0.005	-0.003	0.042	-0.044	0.034	**0.318**	-0.076
IP25	0.164	0.200	0.027	0.175	0.117	0.023	0.020	0.051	-0.025	**0.350**

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

4.11.2 Canonical correlation analyses

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 70, so maximum of seven variables can be taken for canonical analysis.

As a precursor to canonical correlation analysis, the pair-wise correlations between variables were examined and variables were selected to avoid problems of multicollinearity. The bivariate correlation matrix is tabulated in table 4.18 to find out the variables which are highly correlated. The significance of these correlations has been shown in Appendix – C.

Table 4. 18 Correlation matrix

R	IP11	IP12	IP13	IP14	IP15	IP21	IP22	IP23	IP24	IP25
IP11	1.000	0.162	0.086	0.475	0.468	-0.215	-0.041	0.301	0.299	0.321
IP12	0.162	1.000	0.072	0.368	0.351	0.649	0.060	-0.017	0.178	0.414
IP13	0.086	0.072	1.000	0.248	0.420	0.086	0.561	0.386	-0.025	0.097
IP14	0.475	0.368	0.248	1.000	0.669	0.001	0.198	0.412	0.020	0.700
IP15	0.468	0.351	0.420	0.669	1.000	0.085	0.347	0.474	-0.011	0.380
IP21	-0.215	0.649	0.086	0.001	0.085	1.000	-0.017	-0.110	0.095	0.049
IP22	-0.041	0.060	0.561	0.198	0.347	-0.017	1.000	0.417	-0.173	0.074
IP23	0.301	-0.017	0.386	0.412	0.474	-0.110	0.417	1.000	0.167	0.243
IP24	0.299	0.178	-0.025	0.020	-0.011	0.095	-0.173	0.167	1.000	-0.076
IP25	0.321	0.414	0.097	0.700	0.380	0.049	0.074	0.243	-0.076	1.000

Out of the two highly correlated variables, it is tried to consider only one variable and dropping another variable for further analysis to avoid the problem of multicollinearity. The multicollinearity poses a serious threat to further analysis by unnecessarily attaching high weights to some of the variables. The bold entries in table 4.18 indicate the possible indications of multicollinearity, hence out of these two highly correlated variables, one variable has to be dropped. In all, three variables (IP13, IP21 and IP24) have been dropped. Seven variables have been selected for further analysis i.e. canonical correlation analysis.

The canonical correlation analysis has been conducted using SPSS software. One of the SPSS output giving the results of canonical correlation analysis, with all variables included, is shown in Appendix – D. The results shown in table 4.19 indicated a significant canonical correlation function ($r = 0.812$; $p < 0.001$) between sets of the independent and dependant variables. The shared variance is 0.758 and 0.280 for the dependent and independent canonical variates respectively. The redundancy indices were 0.500 and 0.185 for the dependent and independent canonical variates, respectively. The canonical loadings for various independent variables ranged from 0.238 to 0.892. Technological capability, success and flexibility also loaded strongly (0.984, 0.799 and 0.804) in the dependent variate. Canonical loadings measure the correlation between the individual variables and their respective canonical variates, and are similar in interpretation to factor loadings. The cross loadings of independent variables from this analysis indicate that human factor has largest loading on the dependent set with cross loading of 0.724. The next major factor affecting this set of dependent variables is employee education with cross loading of 0.499. Similarly the cross loadings of all other factors are shown against them in table 4.19. 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 analyses.

Table 4.19 also shows the results of these stability runs corresponding to the deletion of IP11, IP12, IP14, 1P15, IP22, IP23 and IP25 respectively. Stability runs resulted in consistent canonical loadings throughout. Therefore, second stage canonical correlation analysis was not required to be run.

Table 4.19 Results of canonical correlation

	Results with all variables		Results after deletion of						
			IP11	IP12	IP13	IP15	IP22	IP23	IP25
Canonical Correlation	0.812		0.792	0.800	0.807	0.679	0.795	0.777	0.808
Canonical Root	0.659		0.627	0.640	0.651	0.461	0.632	0.604	0.653
f statistic	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
DEPENDENT VARIATE	Canonical Cross Loadings	Canonical Loadings	Canonical Loadings						
TC	- 0.807	- 0.984	- 0.961	- 0.991	- 0.996	- 0.971	- 0.985	- 0.991	- 0.990
SCS	- 0.649	- 0.799	- 0.671	- 0.772	- 0.796	- 0.766	- 0.744	- 0.763	- 0.788
FLX	- 0.653	- 0.804	- 0.819	- 0.803	- 0.785	- 0.878	- 0.804	- 0.777	- 0.820
Shared Variance	0.758		0.681	0.741	0.747	0.766	0.724	0.723	0.758
Redundancy Index	0.500		0.427	0.475	0.486	0.354	0.457	0.437	0.495
INDEPENDENT VARIATE	Canonical Cross Loadings	Canonical Loadings	Canonical Loadings						
IP11	- 0.193	- 0.238	--	- 0.266	- 0.241	- 0.308	- 0.291	- 0.281	- 0.249
IP12	- 0.373	- 0.459	- 0.443	--	- 0.465	- 0.526	- 0.460	- 0.478	- 0.458
IP14	- 0.378	- 0.466	- 0.496	- 0.475	--	- 0.599	- 0.482	- 0.478	- 0.477
IP15	- 0.724	- 0.892	- 0.942	- 0.915	- 0.900	--	- 0.929	- 0.945	- 0.900
IP22	- 0.220	- 0.271	- 0.309	- 0.282	- 0.270	- 0.347	--	- 0.287	- 0.279
IP23	- 0.499	- 0.615	- 0.653	- 0.629	- 0.614	- 0.759	- 0.638	--	- 0.624
IP25	- 0.389	- 0.480	- 0.482	- 0.489	- 0.489	- 0.536	- 0.492	- 0.512	--
Shared Variance	0.280		- 0.347	0.308	0.296	0.286	0.340	0.295	0.296
Redundancy Index	0.185		0.218	0.197	0.192	0.132	0.215	0.178	0.193

4.11.3 Multiple regression analyses

Table 4.20 shows that the multiple correlation coefficient (R), using these seven independent variables simultaneously in stepwise method, is 0.799 (R^2 = 0.638) and the adjusted R^2 is 0.609, meaning that 60.9% of the variance in technological capability can be predicted from five variables combined. As the results indicate that, human factor, role of government in new technology adoption, employees' education, impact of globalization and role of top management in technology adaptation are significant, but the other variables will always add a little to the prediction of technological capability. The corresponding f-probability = 0.000 is significant. This indicates that this combination of independent variables significantly predict the technological capability. The standardized beta coefficients are interpreted similarly to correlation coefficients or factor weights. The t value and the significance opposite to each independent variable indicates whether that variable is significantly contributing to the equation for predicting dependent variable from the whole set of predictors. Thus, the human factor, role of government in new technology adoption, employees' education, impact of globalization and role of top management in technology adaptation, in this case, are the variables that are significantly adding anything to the prediction when the other variables are already considered. It is important to note that deleting any one of the independent variable, that is not significant, can affect the levels of significance for other predictors. The tolerance for each of these variables is > 0.391 (1-0.609), indicating that there is no problem of multicollinearity (overlap between independent variables). SPSS output giving the results of multiple regression analysis, using step-wise method, is shown in Appendix – E.

Table 4.20 Multiple Regression Analysis for Technological Capability (step-wise)

Dependent Variable			R	R square	Adjusted R square	F probability	Durben Watson Statistic
Technological Capability (TC)			0.799	0.638	0.609	0.000	2.233
S. No	Independent Variable	B	Beta	Standard error	t-value	Significance	Tolerance
1	IP15	0.644	0.694	0.096	6.688	0.000	0.526
2	IP11	-0.171	-0.306	0.050	-3.414	0.001	0.707
3	*IP23*	0.445	0.327	0.127	3.499	0.001	0.647
4	*IP12*	0.122	0.206	0.049	2.498	0.015	0.833
5	*IP22*	-0.213	-0.201	0.094	-2.278	0.026	0.729

Table 4.21 shows the regression analysis with the dependent variable as success, the multiple correlation coefficient (R), using these seven independent variables using stepwise method, is 0.709 (R^2 = 0.503) and the adjusted R^2 is 0.464, meaning that 46.4% of the variance in Success can be predicted from these three significant variables combined. As the results indicate that, human factor, role of government in new technology adoption, employees' skill, education and attitude, impact of globalization and role of top management in technology adaptation are significant, but the other variables will always add a little to the prediction of success. The corresponding f-probability = 0.000 is significant. This indicates that this combination of the independent variables significantly predict the success. The beta value opposite to each independent variable indicates that the human factor, employee education and impact of globalization are positively correlated to success whereas role of government in technology adoption and role of top management in technology adaptation are negatively correlated to success. The tolerance for each of these variables is > 0.536 (1-0.464), indicating that there is no problem of multicollinearity.

Table 4.21 Multiple Regression Analysis for success due to new technology (step-wise)

Dependent Variable			R	R square	Adjusted R square	F probability	Durben Watson Statistic
SCS			0.709	0.503	0.464	0.000	2.348
S. No	Independent Variable	B	Beta	Standard error	t-value	Significance	Tolerance
1	IP15	0.757	0.569	0.162	4.684	0.000	0.526
2	IP11	-0.436	-0.544	0.084	-5.188	0.000	0.707
3	IP12	0.217	0.256	0.082	2.652	0.010	0.833
4	IP23	0.661	0.339	0.213	3.097	0.003	0.647
5	IP22	-0.436	-0.287	0.157	-2.778	0.007	0.729

Table 4.22 shows the regression analysis with the dependent variable as flexibility, the multiple correlation coefficient (R), using these seven independent variables using stepwise method, is 0.630 (R^2 = 0.397) and the adjusted R^2 is 0.379, meaning that 37.9% of the variance in flexibility can be predicted from these two significant variables combined. These results indicate that, human factor and employees' education are significant, but the other variables always add a little to the prediction of flexibility. The corresponding f-probability = 0.000 and is significant. This indicates that this combination of these independent variables significantly predict the flexibility. The t value and the significance opposite each independent variable indicate that the human factor and employees' education in this case, are the only variables that are significantly adding anything to the prediction when the other variables are already considered. The tolerance for each of these variables is > 0.621 (1-0.379), indicating that there is no problem of multicollinearity.

Table 4.22 Multiple Regression Analysis for Flexibility (step-wise)

Dependent Variable			R	R square	Adjusted R square	F probability	Durben Watson Statistic
Flexibility			0.630	0.397	0.379	0.000	1.386
S. No	Independent Variable	B	Beta	Standard error	t-value	Significance	Tolerance
1	IP15	0.341	0.457	0.080	4.244	.000	0.775
2	IP23	0.292	0.267	0.118	2.479	.016	0.775

This study investigated the role of factors affecting technology adoption and adaptation in fulfilling the objectives of achieving flexibility and building technological capabilities. Flexibility, success due to AMT implementation and technological capability have been described as hierarchical and multi-dimensional entities. Empirical evidence has been presented to support relationships between specific variables and the objectives. The findings suggest that the various factors may be quite important to manufacturing firms trying to compete through flexibility competence and technological capabilities. The human factor in terms of technical expertise, training, involvement and attitude has been found to be the most significant for achieving flexibilities, success and developing technological capabilities individually as well as when considered combined. The other significant factors affecting technological capability came out to be the employees education and the impact of globalization. Another interesting finding is that the role of government in technology adoption and role of top management in technology adaptation is significant but negatively correlated to technological capabilities.

The multiple linear regression of success also indicated that human factor, employee education and impact of globalization are significant and positively correlated to success where as the role of government in technology adoption and role of top management in technology adaptation are also significant but negatively correlated to the success. This implies that the top management in general is not willing to adapt the technologies. Similarly, the multiple regression of flexibility indicated that after human factor, other significant factor is employees' skill, education and attitude. Both are significant and positively correlated to flexibility.

Thus the most significant factor established empirical through this study is human factor in terms of their skill, technical expertise, training, involvement, attitude and employees' education in Indian manufacturing industry for achieving flexibilities and developing technological capabilities.

4.12 IMPACT OF TECHNOLOGY ADOPTION AND ADAPTATION POLICIES ON TECHNOLOGICAL CAPABILITIES

The present status of technology adoption and adaptation policies has been studied in this research work. Insights have been gained regarding existence and usage of these technology adoption policies. Data has also been collected on their updation or review and also regarding tracking of technology adoption costs. The present status of these sub-factors have been summarized in table 4.23.

Table 4.23 Item measures for status of technology adoption policies

S. No.	Item measures for status of technology adoption policies	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Presence of well laid technology adoption	1	21	46	2	189	67.5%

	policies						
ii.	Extensive and thorough use of these technology adoption policies	1	29	34	6	185	66.1%
iii.	The adoption policies include training of the employees at all levels	1	21	39	9	196	70.0%
iv.	The adoption policies include procedures and practices for capability building.	1	28	34	7	187	66.8%
v.	Periodic updation and review of adoption policies	1	27	37	5	186	66.4%
vi.	Tracking of technology adoption costs	2	30	34	4	180	64.3%
vii.	Help of adoption policies in capability building	1	25	42	2	185	66.1%

Table 4.23 shows that within the adoption policies, average scores of various factors are in a narrow range, from 64.3% to 70%. The highest score is awarded for training of employees at all levels, followed by documented procedures and practices for smooth adoption of new technologies. The responses to these sub-factors were averaged to assess the overall status of adoption policies. This has been graphically shown in figure 4.18 with the middle line representing the average value.

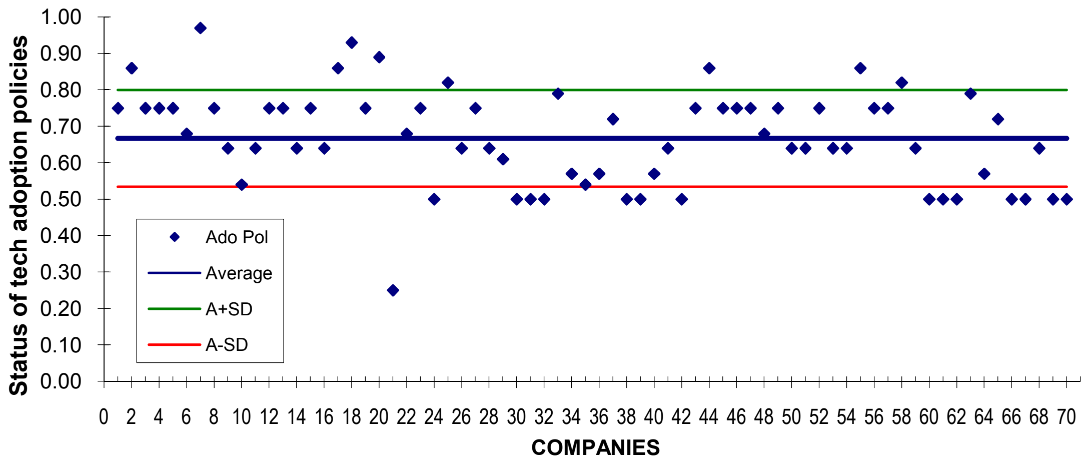

Figure 4.28 Status of technology adoption policies

The overall status of adoption policies is good with average score of 0.67. Among the respondents, the status of adoption policies in 12.9% companies is in very good range, for 37.1% companies in good range, another 28.6% in fair and for remaining 21.4%, the status is poor.

Similarly, the status of technology adaptation policies has already been discussed under section 4.8.5. It is evident from the survey that the present status of technology adoption policies is better that the technology adaptation policies as 97.1 % companies have status of technology adoption policies fair or better as compared to 79.6 % companies in case of technology adaptation policies.

The correlation between technology adoption policies, technology adaptation policies and technological capabilities has been summarized in table 4.24.

Table 4.24 Correlation between technological capabilities, adoption policies and adaptation policies

Correlation	Technological capabilities	Technology adoption policies	Technology adaptation polices
Technological capabilities	1.000	0.288 (0.016)	0.400 (0.001)
Technology adoption policies	0.288 (0.016)	1.000	0.707 (0.000)
Technology adaptation polices	0.400 (0.001)	0.707 (0.000)	1.000

The values in parenthesis indicate the significance level of correlation. It is evident from the correlations that there exist a small but significant association of technological capabilities with technology adoption and adaptation polices. However the comparative association of technological capabilities is somewhat stronger and more significant with technology adaptation policies than its association with the technology adoption policies. So this implies that technology adaptation policies assist in building technological capabilities better than technology adoption policies do.

4.13 BARRIERS TO TECHNOLOGY ADOPTION

The data regarding the relative severity of various possible barriers of technology adoption were also collected through the survey. After thoroughly reviewing the literature, twenty four probable barriers to technology adoption were identified. Responses and relative scores of these are summarized in table 4.25.

Table 4.25 Severity score of barriers to new technology adoption

S. No.	Severity score of barriers to new technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Cost of new technology acquisition	7	10	25	28	214	76.4%
ii.	Cost of training and education	5	6	30	29	223	79.6%
iii.	Problems with compatibility of equipment	20	10	24	16	176	62.9%
iv.	Skill deficiency for new technology	18	9	21	22	187	66.8%
v.	Production management skill deficiency	38	10	18	4	128	45.7%
vi.	Disruptions during implementation	12	6	18	34	214	76.4%

S. No.	Severity score of barriers to new technology adoption	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
vii.	Adverse effect on work flow	19	6	15	30	196	70.0%
viii.	Risk of failure to achieve financial targets	25	18	17	10	152	54.3%
ix.	Inadequate flexibility in regulations	12	18	22	18	186	66.4%
x.	Lack of customers' responsiveness to new products	26	20	14	10	148	52.9%
xi.	Workers' resistance	11	9	22	28	207	73.9%
xii.	Increased maintenance expenses	8	7	29	26	213	76.1%
xiii.	Need for market expansion	17	23	22	8	161	57.5%
xiv.	Lack of financial justification	26	14	21	9	153	54.6%
xv.	Lack of qualified personnel	20	6	24	20	184	65.7%
xvi.	Lack of information on technology	30	6	26	8	152	54.3%
xvii.	Lack of information on markets	19	11	28	12	173	61.8%
xviii.	Lack of support from vendors	12	11	26	21	196	70.0%
xix.	Lack of marketing capabilities	14	21	22	13	174	62.1%
xx.	Organizational rigidities within enterprise	18	18	24	10	166	59.3%
xxi.	Lack of appropriate sources of finance	12	8	32	18	196	70.0%
xxii.	Inability to devote staff to projects	25	6	24	15	169	60.4%
xxiii.	Lack of industry wide standards	18	7	26	19	186	66.4%
xxiv.	Likely obsolescence of technology	27	13	17	13	156	55.7%

Among these 24 barriers, the ranking has been done on the basis of their score or percentages. The overall severity score of all the barriers is moderate to high and none of the barriers got very high score which imply that though the barriers do exist but these can be overcome in Indian manufacturing industries.

4.13.1 Critical barriers to technology adoption

The most severe barrier has been found to be the cost of training and education for adopting new technology with scoring of 79.6%. Since this forms the intangible capability of the company and is highly dependent on the human factors like their attitude, education and willingness to accept changes, it scored higher than the tangible barrier 'cost of new technology'. It is then followed by two barriers with equal score of 76.4%. These are 'cost of new technology acquisition' and 'risk of possible disruptions during new technology implementation'. The cost has always been one of the biggest barriers to new technology adoption and it has to be justified before starting. The new technology is usually adopted when existing technology cannot cope with market requirements and, at the same time, new technology implementation disrupts the routine work, which is highly undesirable and thus it becomes a major barrier.

Other severe barriers according to their severity are 'increased maintenance expenses' and 'workers' resistance'. New technology usually has low frequency of breakdown or maintenance requirements, but whenever the maintenance is required, it is very expensive and usually can be carried out only by the vendor of the technology at handsome charges. Workers' resistance has also been found to be an important barrier, because the new technology being highly productive and involving high degree of automation, may require less people to work with it, thus resulting in some layoffs. Or sometimes, new technology is associated with new procedures and practices, for which workers have to be trained, so the workers offer resistance to adoption of new technology. But this can be minimized by communicating benefits of new technology among the workers and assuring them of easier and safe procedures associated with new technology adoption.

'Adverse effect on work flow', 'Lack of support from vendors' and 'Lack of appropriate sources of finance' are the barriers that come next equally with severity score of 70%. During the process of new technology adoption and implementation, the existing work flow gets suffered, so the already fixed production targets are likely to be missed and the fear of missing the target dates usually acts as barrier to new technology adoption. The lack of support from the vendors of new technology also acts as a big obstacle. No company may go for new technology adoption till it is assured of support from vendors. Sometimes, there could be some problem with sources of finance, as new technology adoption may require huge capital investment and at the same time associated with the risk of its success, the financial institutions' resistance to advance loan or problem in raising money through other sources like public issue may act as barriers to new technology adoption. Formation of state financial corporations by various state governments to advance loans to manufacturing industries is one effort to overcome this barrier.

Skill deficiency has been found to be the ninth barrier to technology adoption from the severity point of view. A company may not have enough technical and skilled staff to cater to the requirements of new technology. So without strengthening the work force with adequate technically qualified and skilled personnel, the skill deficiency acts as the barrier to technology adoption.

'Inadequate flexibility in regulations' and 'Lack of industry wide standards' are the barriers that come next with score of 66.4%. For some companies, the regulations may not be flexible enough to introduce new technologies and in spite of valid and clear justification for new technology adoption, it may not be done.

Among the least important barriers to technology adoption are 'lack of customers' responsiveness to new products' and 'production management skill deficiency'. The customers usually show their responses to new and improved products, which are produced by new technologies. It has been found out that the Indian manufacturing industry does not have much management skill deficiency because this barrier to technology adoption has severity score of 46.4%.

It can be concluded from the above discussion that among the listed barriers to technology adoption, none has got a score over 80% or below 20%, which implies that no severe barrier to technology adoption exists and at the same time no barrier is purely insignificant. Further, this analysis has indicated only the relative severity of barriers to technology adoption in Indian manufacturing industry.

4.13.2 Actions required for overcoming the barriers to new technology adoption

The following are the critical barriers to new technology adoption (in order of severity):

- Cost of training and education
- Cost of new technology acquisition
- Disruptions during implementation
- Increased maintenance expenses
- Workers' resistance.

Though the 'cost of training and education' has been found to be the most critical barrier to the new technology adoption, but without investing properly in training and education of the new technology, its benefits can't reaped. It's only after the training of people in new technology, that it can be fully adapted and then utilized. Training affects the human factor which has been identified in this research as the most important factor for achieving flexibilities and developing technological capabilities. Training can enhance the skills of the employees, change their attitude and elevate their level of education. The organizations must not consider training as a liability, rather human resource development must be considered as one of the most important intangible assets. However, organizations can overcome this barrier to technology adoption by:

- Adopting policies to retain its trained manpower in order to avoid the repetitive expenses on trainings of adopted technologies.
- Developing capabilities to train the manpower in-house through special programmes like 'train-the-trainer' in which a few employees should be well trained in a particular technology, then these employees further train the other people of the company.
- Documenting training procedures and details in form of training manuals to the best possible extent.

The second most critical barrier to new technology adoption is'cost of technology acquisition'. There is no doubt that new technology adoption is associated with a lot of expenditure on its acquisition, but if a new technology is successfully adopted, adapted and utilized, it will payoff very easily. The managers often view advanced technology as an expense rather than a strategic investment. They also fear that technology adoption can be a never-ending process; one that causes expenses to spiral out of control. The common thread is that many executives feel that they cannot afford advanced technologies, whether or not their feelings are valid.

Organizations can overcome this barrier by:

- Documenting direct benefits and ROI of advanced technologies in an unbiased manner.
- Viewing new technology as a strategic asset.
- Demonstrating ancillary benefits and their effect on ROI.
- Suggesting cost-effective ways to implement advanced technologies.

The next critical barrier to new technology adoption is 'disruptions during implementation'. It takes some time for implementation when existing technology is replaced with new technology. During this period, the routine manufacturing processes are discontinued and it affects the scheduling of organizations in meeting the target delivery dates. In order to avoid such delays, the managers sometimes avoid to upgrade the technology until the dire need of it arises. Organization can overcome this barrier to new technology adoption by:

- Implementing new technology in a phased manner, so that only a small part of existing system is affected at a time.
- Maintaining a buffer stock of goods to be supplied during new technology implementation.
- Crashing of project, wherein the various activities involved in technology implementation are carried out concurrently but at some higher cost.
- Proper planning and scheduling the events of new technology implementation, so that it does not affect the routine processes during implementation.

The fourth critical barrier to new technology adoption is increased maintenance expenditure'. There is no doubt that the every next generation of new technology is associated with so many benefits but at the same time it puts much pressure on the maintenance expenditure of the company. The maintenance of new technology requires special expertise in handling the latest equipment. Most of the time, the new technology is maintained by its supplier. But in case of imported technology, frequent maintenance by the technology supplier is not economically feasible. So, the adopting companies must develop internal capabilities of maintaining it through extensive training. Organizations can overcome this barrier to new technology adoption by:

- Providing extensive training to the organizations' maintenance personnel from the technology supplier at the time of technology acquisition.
- Adopting policies to retain its trained manpower in order to avoid the repetitive expenses on trainings of maintenance of adopted technologies.
- Extending the term of maintenance to be provided by its supplier in the initial contract.
- Carrying out in-house research and development, for understanding the underlying principles of new technology.
- Carrying out reverse engineering on the adopted technology.

'Workers' resistance' has been established to be the fifth most critical barrier to the technology adoption. Resistance to change is the natural phenomenon for human beings. Workers feel that the new technology will require enhanced skills and their fear about their own adaptability with new technology give birth to their resistance. Moreover, the fear of layoffs due to new technology also creates the resistance among workers. The workers' resistance may be minimized in the organization by taking the following steps:

- Involving them in the process of new technology adoption.
- Making them aware of the objectives and benefits of technology adoption in a clear manner.
- Motivating them to accept technological changes.
- Preventing misunderstandings, clarifying objectives, and establishing measurable guidelines for results.
- Providing job security
- Developing a mechanism for rewards and recognitions to these workers, who show interest in training of new technology
- Developing a culture of open communication within the organization.

4.14 BARRIERS TO TECHNOLOGY ADAPTATION:

Data regarding the severity of various possible barriers to technology adaptation were collected through the questionnaire. After thoroughly reviewing the literature, eight possible barriers to technology adoption were identified. Respondents' responses and score of these are summarized in table 4.26.

Table 4.26 Severity score of barriers to new technology adaptation

S. No.	Item measures for success due to new technology	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Problems with compatibility of equipments	16	25	14	15	168	60.0%
ii.	Adverse effect on work flow	18	16	15	21	179	63.9%
iii.	Inadequate flexibility in regulations	13	35	17	5	154	55.0%
iv.	Lack of in-house technical support	15	14	22	19	185	66.1%
v.	Lack of information on technology	19	26	25	0	146	52.1%
vi.	Lack of support from vendors	19	20	25	6	158	56.4%
vii.	Organizational rigidities within enterprise	27	17	17	9	148	52.9%
viii.	Lack of industry wide standards	33	29	7	1	116	41.4%

Among these eight barriers, the ranking has been done on the basis of their score or percentages. The overall scoring of all the barriers is moderate to high and none of the barriers scored very high. This implies that though the barriers do exist but these can be overcome by the manufacturing industries.

4.14.1 Critical barriers to technology adaptation

The most severe barrier has been found to be the lack of in-house technical support for adapting new technology with a score of 66.1%. Since the adaptation involves the modification of technology and processes to suit local conditions, technical support is a must for this process. Though the vendors of technology may help in initial adaptation of technology, but for day-to-day routine operations and minor problems, in-house technical support is required, and lack of it is the biggest barrier to technology adaptation in Indian manufacturing industry.

'Adverse effect on work flow' is the second major barrier to technology adaptation with score of 63.9%. The routine work is normally disturbed during the process of technology adaptations and there is always a risk of production loss, which is considered as a barrier to technology adaptation by most of the companies. The third major barrier to technology adaptation is 'Problems with compatibility of equipment', with average score of 60%.

The least important barrier has been found to be 'the lack of industry wide standards', which implies that the standards in manufacturing industry are either well established, or standards vary in various sectors of industry.

4.14.2 Actions required for overcoming the barriers to new technology adaptation

The following are the critical barriers to new technology adaptation:

- Lack of in-house technical support
- Adverse effect on work flow
- Problems with compatibility of equipment

The most severe barrier to the adaptation of new technology, established through this research is, lack of in-house technical support, which is otherwise a very important factor for adaptation of new technology. This lack may be on the account of incapability of in-house technical team in handling the new sophisticated technology or sometimes, their attitude of not providing support. The following actions can help to overcome this barrier to technology adaptation:

- Providing training and education for internal technical team.
- Motivating the concerned people.

- Empowering in-house technical team
- Rewarding and recognizing interested, sincere and hardworking people.

The second most severe barrier to new technology adoption has been found to be the ‘adverse effect on work flow’ during adaptation of new technology. Whenever the technology is adapted, it takes some time. During this period, the routine manufacturing processes are discontinued and it affects the scheduling of organizations in meeting the target delivery dates. In order to avoid such delays, the organizations sometimes don’t adapt the technology until the dire need of it arises. The organization can overcome this barrier to new technology adaptation by:

- Adapting new technology in a phased manner, so that only small part of existing system is affected at a time.
- Using soft technologies offline to customize these as per the local requirements.
- Maintaining a buffer stock of goods to be supplied during new technology implementation.
- Crashing of project, wherein the various activities involved in technology adaptation are carried out concurrently but at some higher cost.
- Using design software to simulate the entire manufacturing processes and plan technology adaptations offline, which would subsequently be implemented in shorter time.
- Proper planning and scheduling of the events of new technology implementation, so that it does not affect the routine processes during implementation.

The third most severe barrier to technology adaptation is ‘problems with compatibility of equipment’. Most of the advanced technologies (hard or soft) adopted by manufacturing organizations are commercially available ones. In general, commercial off-the-shelf technologies require organizations either to adapt the technology to suit local environment or modify their processes and procedures to fit the technology. However, if the required changes are very extensive and pervasive, they indicate a lack of fit i.e. the incompatibility which may cause dissatisfaction and can discourage the organizations from adopting critically needed hard or soft technologies in future. Organizations can overcome this barrier by:

- Providing strong in-house technical support to make new technological components compatible with the existing one.

- Planning workshops and tutorials in case of soft technologies.
- Critically analyzing technology before adoption to check, and planning for all incompatible issues.

4.15 PROBLEMS FACED WHEN OLD AND NEW TECHNOLOGY ARE BROUGHT IN CONTACT

Whenever a new technology is adopted and implemented, a time comes when old and new technologies come in contact with each other, and this results in some problems. After going through literature and field survey during pilot test, twelve different types of problems were identified. Responses to these problems and their aggregate score by seventy companies have been summarized in table 4.27.

Table 4.27 Severity score of problems that occur when existing and new technologies are brought into contact

S. No.	Item measures for success due to new technology	Number of responses (Ni) with each score choice (Si)				Total Score	%age
		1	2	3	4		
i.	Risk of production loss	10	16	24	20	194	69.3%
ii.	Lack of knowledge about new technology	7	34	18	11	173	61.8%
iii.	Difficulty in operating and maintaining new technology	6	21	31	12	189	67.5%
iv.	Lack of co-operation and understanding	12	19	32	7	174	62.1%
v.	Fear of Layoffs	9	18	21	22	196	70.0%
vi.	Resistance to change	8	22	20	20	192	68.6%
vii.	Lack of action oriented strategies	26	22	14	8	144	51.4%
viii.	Inadequate internal skills	20	27	11	12	155	55.4%
ix.	Lack of motivation	25	22	13	10	148	52.9%
x.	Lack of management information system	31	21	15	3	130	46.4%
xi.	Inability to migrate to new technology	19	17	23	11	166	59.3%
xii.	Lack of proper infrastructure	17	20	17	16	172	61.4%

It has been observed that in this case also, no problem has score over 80%, so none of the problems is very severe. The highest score is with a problem 'fear of layoffs' with score of 70% which still dominates the Indian manufacturing industry. The new technology involves higher productivity, improved and easier methods, highly skilled maintenance team etc which may require existing workforce to be highly downsized. So the fear of layoffs is mostly seen as a major problem when new and old technologies are brought into contact.

It is then closely followed by the 'risk of production losses with score of 69.3%. The new technology adoption causes disruption in existing production and it becomes the major problem to continue to meet market demand and at the same time to upgrade to new technology.

The problem of resistance to change scores the third rank with score of 68.6%. Everyone feels comfortable with the existing technology and all have to change their work styles, procedures, methods etc to work with new technology. So the resistance to change is a considerable problem while implementing new technology. It can be taken care of by proper training and motivation of work force.

'Difficulty in operating and maintaining new technology' is the next problem with average score of 67.5%. The new technology, after implementation, have to be operated by work force which though have been trained for it, but still since the methods and procedures are new, the workforce is not well experienced with these and is habitual of using methods associated with old technology and therefore often face difficulties in operating and maintaining new technologies.

The least scoring problems are 'lack of action oriented strategies' and 'lack of management information system' with average score of 51.4% and 46.4% respectively.

4.16 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. These learning issues have been listed below and will be synthesized in the qualitative modeling for developing the implementation plan.

4.16.1 Learning issues based on descriptive analysis

Concerning technology adoption

- Most of the companies have always been adopting new technology in the past to match their requirement.
- One third of the companies adopt new technology immediately on its availability and one sixth of the companies adopt only when there is dire need of it.

- Around 80% of the companies adopt new technology for some or more of the important processes.
- Around 89% of the companies consider the alternate process that can be developed in house for making new technology cost effective.
- Almost all the companies conduct some analysis based on the trends of the past years before going for new technology.
- All the companies go for economic viability study for adopting new technology.
- Around 86% of the companies considerably look into consequential changes in related products and processes, whereas 3% companies do not take any such consideration in account.
- Around 34% of the companies involve the manpower from the very beginning.
- The government through its agencies encourages 25% companies to adopt new technologies.
- 32% of the companies adopt new technology due to govt. regulations (environment or pollution related).
- Around 33% of the companies adopt new technology due to incentive provided by the govt. for the purpose.
- Most of the companies consider the opportunities or threats caused by the globalization as a justified reason to adopt new technology.
- The availability of new technology due to globalization is a significant factor for adopting new technology.
- Top management always provides full support in all companies for new technology adoption.
- Most of the companies have written formal manufacturing strategies which helps in their technology upgradations.
- Understanding the benefits of new technology assists in adoption in 87% companies.
- Well defined objectives of new technology helps in its adoption in 87% companies.
- Most of the companies have well defined technology adoption policies, though these policies are used to varying extents in companies.

- In most of the companies the technology adoption policies include training of the employees at all levels.
- These policies are updated regularly in only 60% companies.
- Technology adoption policies help in capability building of 63% companies.
- Human factor plays a crucial role in new technology adoption in all the companies.
- In-house engineers actively participate in new technology adoption in 90% of the companies.
- Aligning the attitude of employees towards objectives of new technology smoothens its adoption process in 93% of the companies.
- For adopting new technology, all companies use formal education and training programmes for employees at all levels.

Concerning technology adaptation

- In 63% companies, there is considerable need of redesigning production systems to achieve ergonomics and safety layout of machines whereas 50% of companies need some standardization of equipment.
- There is some need of redesigning the organization structure and considerable need of internal shifting of people in 63% companies.
- Almost all companies may need to recruit suitable persons from outside for successful adaptation of new technologies.
- There is considerable need of imparting training to personnel and designing new methods of performance and efficiency measurement.
- In 44% companies, considerable efforts have to be put in to make new technology acceptable to employees.
- Considerable changes in manufacturing, product design and features, plans and procedures have to be implemented during technology adaptations.
- The effectiveness of the technology adaptation process can be considerably enhanced by empowerment, extensive training, open communication within the company, job security to employees and rewards and recognition.
- There is negligible role of govt. in adaptation of new technology.

- The top management provides support for technology adaptation and allocates sufficient funds for the same in all companies.
- Top management is also ready for taking short term risks in order to have long term pay offs in all companies.
- Skilled workers help in easy adaptation of new technology as compared to unskilled counterparts in 93% companies.
- Technocratization is found to be a key factor responses for technology adaptation in 83% companies.
- In 84% companies, employees are willing to accept changes.
- Staffing flexibilities & production flexibility of company assists in technology adaptation.
- 83% companies indicate the severity of in-house R&D for new technology adaptation.
- Technology adaptation policies exist to some extent in 71% companies
- Wherever exist, these include training of employees, procedures and practices for smooth adaptation of technology.

Concerning technological capabilities

- 57% companies are aware of technology issues and the need to acquire technologies to a large extent.
- 81% companies have the ability to a large extent to seek out and identify technologies to solve particular problems.
- 73% companies have built distinctive capabilities to a large extent in some area of technology.
- 67% companies can develop a technology strategy, including a framework with priorities and an action plan.
- The ability to assess and select cost effective technology solutions is possessed to a large extent by 69% companies.
- 84% companies are carrying out the acquisition and absorption of specific technologies.

- Only 37% companies possess, to a large extent, the skills involved in making effective use of technology, whereas another 41% companies possess such skill to considerable extent.
- The ability to learn from and accumulate experience in order to continuously improve capabilities is possessed to a large extent by 73% companies.
- 60% companies possess the ability to considerable extent to form and exploit linkages with networks of technology suppliers and others involved in technology, whereas only 19% companies possess such abilities to a large extent.

Concerning technology adoption and adaptation policies

- 97.1 % companies have status of technology adoption policies fair or better as compared to 79.6 % companies in case of technology adaptation policies
- Technology adaptation policies have stronger impact on technological capabilities as compared to technology adoption policies.

Concerning critical barriers to new technology adoption

- The following are the critical barriers to new technology adoption (in order of importance):
    - Cost of training and education
    - Cost of new technology acquisition
    - Disruptions during implementation
    - Increased maintenance expenses
    - Workers' resistance.

Concerning critical barriers to new technology adaptation

- The following are the critical barriers to new technology adaptation (in order of importance):
    - Lack of in-house technical support
    - Adverse effect on work flow
    - Problems with compatibility of equipment

Concerning problems faced when existing and new technology are brought into contact

- The following problems are faced when existing and new technology are brought into contact (in order of importance):
    - Fear of lay-offs
    - Risk of production losses
    - Resistance to change
    - Difficulty in operating and maintaining new technology
    - Lack of co-operation and understanding

4.16.2 Learning issues based on empirical analysis

Concerning correlation analyses

- Technological capabilities has a very strong and significant association with other dependent variables i.e. the success due to new technology ($r = 0.838$, $p = 0.000$) and flexibility ($r = 0.746$, $p = 0.000$).
- Further, the technological capabilities also have strong and significant association with impact of globalization ($r = 0.382$, $p = 0.001$); role of top management ($r = 0.353$, $p = 0.003$); manufacturing strategy and technology adoption policies ($r = 0.525$, $p = 0.000$); human factor ($r = 0.709$, $p = 0.000$); employees' education ($r = 0.478$, $p = 0.000$) and technology adaptation policies ($r = 0.400$, $p = 0.001$).
- Manufacturing strategy and technology adoption policy has very strong association with human factor ($r = 0.669$, $p = 0.000$) and technology adaptation policies ($r = 0.700$, $p = 0.000$). As it may pose the problems of multicollinearity among independent variables, so it has not been used further in canonical correlation analyses and multiple regression analyses.
- Role of government in technology adaptation has strong and significant association with role of government in technology adoption ($r = 0.649$, $p = 0.000$), so it has also been dropped for further analysis to avoid problems of multicollinearity.

Concerning canonical correlation analyses

- Human factors in terms of their skill, technical expertise, training, involvement and attitude has the highest cross-loading (0.724) among the independent variate.

- Employees’ education has come out to be second most significant factor affecting technological capabilities, success of technology adoption and adaptation and flexibility with cross loading of 0.499.

Concerning multiple regression analyses

- In multiple regression analysis using stepwise method, human factor, role of government in new technology adoption, employees’ education, impact of globalization and role of top management in technology adaptation are found to be significant in the prediction of technological capability.
- Human factor, role of government in new technology adoption, employees’ education, impact of globalization and role of top management in technology adaptation are found to be significant in multiple regression analysis (using stepwise method) of success due to technology adoption and adaptation.
- The results of stepwise multiple regression of flexibility indicates that human factor and employees’ education are significant in the prediction of flexibility.

4.17 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 technological capabilities. 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 different dependent variables with the independent variables, the multiple regression analyses have been done using step-wise method to avoid problems of multicollinearity. The learnings 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 the results presented in this chapter.

CHAPTER V

CASE STUDIES ON FLEXIBLE MANAGEMENT OF TECHNOLOGY ADOPTION AND ADAPTATION

5.1 INTRODUCTION

This chapter describes the detailed case studies carried out in various manufacturing organizations, which are actors in this context. The objective of carrying out case studies was to look deep into and to critically analyze various facets of working of these organizations in general and processes followed for technology adoption and adaptation for building technological capabilities. These case studies were conducted in a phased manner starting from the evolution of the need for incorporating the technological capabilities by flexibly managing the new technology adoption and adaptation in different manufacturing organizations. The current status, performance and financial indicators, process of technology adoption and adaptation, and technological capability achieved have also been studied. These case studies have been analyzed and their results have depicted the industrial scenario about the research objective. The preliminary information provided by the survey has been validated by these case studies.

To carry out case studies, criteria for selection of organizations have been discussed in Chapter – III, Design of the Study.

Based on the criteria, four companies, namely: Maruti Suzuki India Limited (MSIL), Gurgaon; Sona Koyo Steering Systems Limited (SKSSL), Gurgaon; Moserbaer India Limited (MIL), Noida; and Punjab Tractors Limited (PTL), Mohali were selected. Generic, atomic, static, and singular type SAP-LAP analyses using SWOT study have been prepared for each case study.

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 75 lakh vehicles, including almost five lakh units in European and other export markets. The company presently has a wide product range of 11 models with around 100 variants in the market. A Board of Directors with chairman from M/s Suzuki Motors Company (SMC) of Japan manages the affairs of the company. MSIL has been a fast growing company and has expanded its product range to suit a large spectrum of customers in and outside India over the years. 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).

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. It was incorporated 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, and 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 the company was to determine the most suitable product mix and to select the most suitable foreign partner who would be willing to accept its 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 October, 1982, by which SMC acquired 26% share of the equity with an option to increase it to 40%. 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.13229.2 lakh. SMC holds 54.2% stake in the company, as on 31st March, 2008 and provided access to some of its products, licensed its technology, shared its best practices in manufacturing processes and helped to develop and manage the supply chain.

The company has two manufacturing facilities in India, one in Gurgaon and the other in nearby Manesar. Gurgaon facility houses three fully integrated plants. While these 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 global ambitions of Suzuki Motor Corporation and Maruti Suzuki India Limited. Rated high among Suzuki's best plants worldwide, Manesar plant was inaugurated in February 2007. This plant has several in-built systems and mechanisms to ensure that cars being manufactured here are of high 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, robots have been equipped in those areas, where manual operations are hazardous or unsafe. 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 1 lakh cars per year. This will be scaled up to 3 lakh cars per year. A total investment of Rs. 2,500 crore will be made in this car plant by 2010.

Suzuki Powertrain India Limited at Manesar is first and the only plant designed to produce world class diesel engines and transmissions for cars. The plant is under a joint venture company, in which SMC holds 70% equity with the rest held by MSIL. This facility has an initial capacity to manufacture 1 lakh diesel engines a year. This will be scaled up to 3 lakh engines per year by 2010. The diesel engines manufactured at this plant will also be exported to SMC companies across the world. 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.

5.2.1 Company's competitive 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 has 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 in the global business arena. Through the years, Maruti brought in relevant products to the market even before the market demands were expressed. 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.

A chronology of milestones achieved by MSIL since its inception, have been delineated in the Table 5.1.

Table 5.1 Milestones of Maruti Suzuki India Limited

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 and 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. • First car company in India to launch a call center.
2001	• Turn over with profits Rs. 104.5 crores. • Maruti Versa launched. • Maruti true value 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 and 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 programs 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 will hold a 30% stake in the venture whereas Bellsonica will hold 70 percent stake.

2007	• New Car plant and the diesel engine facility commenced operation during 2006-07 at Manesar, Haryana. • SX4- Luxury Sedan launched with the tag line "Men are Back". • Maruti Launched Grand Vitara. • Launched Swift Diesel, Zen Estilo, WagonR with facelift, WagonR Duo (LPG), and immobilizer equipped models.

5.2.2 Performance indicators

The snapshot of the performance of the company and trends in various performance indicators are shown in Figure 5.1.

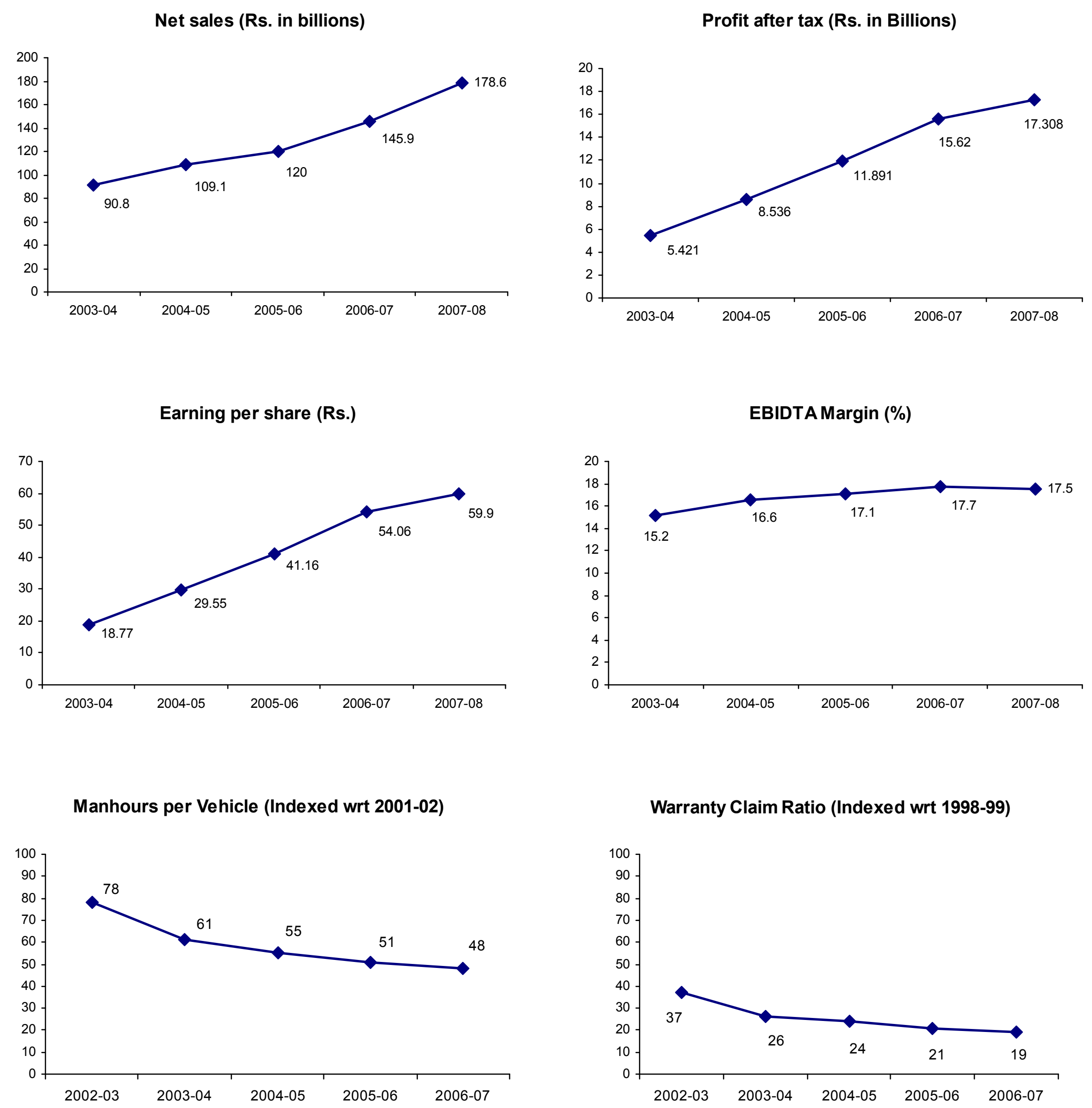

Figure 5.1 Performance indicators of Maruti Suzuki India Limited

Net sales of the company is showing a consistently rising trend. Net sales were Rs. 90.8 bn in 2003-04 which 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. During

2006-07, the increase in net sales is tremendous. The year was significant also for the success of all company new product launches, entry into cars powered by diesel and LPG, development of new markets for exports and the continued rapid expansion of sales and service network. 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. 178.6 bn in year 2007-08.

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 (EPS) for 2004-05 were at Rs. 29.55, against Rs. 18.77 in 2003-04, showing a marvelous rise of 57.4%. EPS 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, EPS for 2006-07 increased by 31.3% to Rs. 54.06 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.

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. EBITDA margin 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.

Manhours per vehicle (an inverse indicator of productivity) is showing a continuous falling trend thus representing an increase in productivity. Manhours per vehicle were indexed to 100 for the year 2001-02, its value for the year 2002-03 worked out to be 78. This value 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 (an inverse indicator of quality) also shows a continuous falling trend, thus depicting a continuous rise in quality of products. When warranty claim ratio was 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 indicates that the company is constantly upgrading its manufacturing processes and taking a series of initiatives to ensure consistency in product quality.

5.2.3 Current practices

The company has built capacities, technological capabilities and management bandwidth through the use of advanced manufacturing technologies in recent years. This was evident in the continued expansion of the company's sales and service network, and the growth in manpower in the field. Further, there were efforts to enhance design and development capabilities within the company. The diesel powertrain plant at Manesar is a state-of-the-art facility and Suzuki's first diesel venture meant to feed its global operations from India.

Improving productivity is an ongoing effort at Maruti, through the Maruti Production System (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.

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.

The company has launched 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.

With increased competition, stringent automotive regulations and increased customer expectations, there is 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 setting up challenging cost reduction targets for specific existing models. Thereafter, the company 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. With this, the company was able to reduce its ratio of material cost to net sales from 76.8% in 2005-06 to 75.7% in 2006-07, despite steep increase in commodity prices in year 2006-07.

Role of technology in manufacturing

The engineering and technology area of the company has progressed from introduction of special editions, upgrades and new variants, to building the capability for facelift of models, to designing contemporary world cars such as Swift and Zen Estilo jointly with SMC. Now, it is gradually shaping up to become the design hub of SMC for its Asian operations outside Japan. Over 430 dedicated engineers are working closely with their counterparts at SMC for developing design capabilities of the company. Two Maruti models, Wagon R and Esteem, were ranked first in the JD Power Asia Pacific Survey on Automotive Performance, Execution and Layout (APEAL). `

The achievements in the market place have been supported by improved productivity and quality on the shop floor. During three-year period (2002-05) the company was able to improve shop floor productivity by 46% and bring down cost by nearly 30%. As a result, at Gurgaon 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.

Besides, 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. The net impact of all these efforts in operations is that the cost of many of the models like Alto, Esteem and Maruti 800 these days is less than 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.

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 much less 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. Credit for this goes, in large part, to the new design philosophy at SMC where new models are increasingly inspired by contemporary European design and hence are more bold and aggressive. Growing design capability in the area of cars, components and dies within the company has fostered their target cost approach.

In the past 3-4 years, the company has started any new model exercise by first identifying a target price at launch. Based on that, the company arrives at the target cost for individual components and processes. This has worked successfully with new models like Swift and SX4. The company was able to offer more features than competitor products, at a lower price. Given a target cost, there are innovations along the entire value chain to meet the target. As an outcome, newer models like Swift and Estilo were launched with as high as 90% and 85% levels of localization, respectively to meet stringent target cost. Another initiative to meet tight target cost targets has been greater use of digital design and manufacturing to shorten lead times and bring down costs.

Alto is a shining example where Maruti was able to cut down the prices drastically through collaborative efforts. A cross-functional team (CFT) was formed involving people from different business functions like Supply Chain, Engineering and Marketing Divisions. The components cost has reduced by 30 percent over the period by this effort.

Role of technology in product development

The product development cycle at Maruti Suzuki has been considerably shortened to respond to market conditions. Launch of five models was seen in last two years, which is new to Indian auto industry. The 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 efficiency improvement methods at each level are implemented. Cost reduction is looked into at every stage. Adopting new technologies like the Digital Mockup and Ergonomics Simulation helped 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.

R&D activities of MSIL have the twin objectives of reducing product costs by developing capabilities of local vendors and becoming a regional R&D hub for all SMC 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 carries 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. MUL regularly upgraded its models and also launch variants by adding features developed through its research and development activities.

Role of technology in system design (digital manufacturing)

The company has recently adopted a new soft technology known as Digital Mockup or Digital Manufacturing to bring out cars at rapid pace. The new model introduction time has now reduced by 25%. The company has launched five new models, Wagon R-LPG, Zen Estilo, Swift Diesel, SX4 and Grand Vitara in less than two years. Earlier it used to be one model every two years. Benefits of using digital manufacturing included (a) reduction in time-to-market by shortening lead-time, (b) reducing costs of the manufacturing planning processes as well as product development in general by streamlining production planning, (c) assessing production feasibility of a model by simulating manufacturing operations before the beginning of production, (d) reduction in the number of prototypes by using digital mockup and line simulations, and (e) improving collaboration, by providing early access to design, process, and resource information in a controlled environment.

Adoption of integrated information and communication technologies

Integrated information and communication technology (ICT) 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. MSIL embraced (ICT) right at its inception. Today, ICT embraces all critical processes including product development and manufacturing and is a crucial tool in the operations of MSIL. Broadly, IT has strengthened the organizational capabilities in the following four areas

1. keeping low inventory – a pre-requisite for 'Lean Manufacturing',
2. giving it flexibility to manufacture 11 different models with over 100 variants,
3. enabling better service to the customers by ensuring smooth flow of cars and spares across a national sales and distribution network, and
4. improving customer interface in many ways.

If numbers were any indication of the volume of the business, 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 ICT enabled and quality is maintained at a consistent level.

ICT 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 ICT 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. The ICT adoption has been systematically presented in the Table 5.2.

Table 5.2 ICT adoption at Maruti Suzuki India Limited

Categorization of IT/ ERP systems	**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 adopted 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. Scheduling algorithm is designed to study past consumption pattern as well as future production plan. Bar Code based document processing is used to minimize document handling cost and time
Warehouse Management System (WMS)	Managing inventory of spares can be taxing in absence of accurate IT solution. To simplify this exercise WMS was adopted which could facilitate increased inventory turnover and faster turnaround time.
Vehicle Tracking System (VTS)	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. Re-certification for ISO27001 is in the offing for the next financial year.
Dealer Management System	Newly implemented 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 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.

5.2.4 New technology – adoption and adaptation

The company is working towards localization, development and testing of its products - both new and existing. To achieve this, it is adopting and adapting new technologies at a very fast pace. For instance, say company wants to add a new feature to its new models like Headlamp Leveling Device. Due to its technological capabilities, it first imports and adopts new technology for providing this feature. It adapts this technology and using teardown approach and reverse engineering, the same technology is then developed in-house with almost complete indigenization. This helps in indigenization of various vehicle aggregates at lower costs. Launching of Zen Estilo, with 94.2% localization is a case in point. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization are helpful in further improving and upgrading existing models for comfort, style and value for money. Alternative fuels like CNG and 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.

The following section lists in brief the different technologies adopted during previous years, benefits derived due to these adoptions, efforts done for technology adaptations and its benefits.

New technologies were adopted in following areas during year 2003-04:

1. Building Minor Change Capability
    - Clay Model Making for body shape change
    - Designing of body panels for facelift.
    - Shift from to Uni-Graphics designing software to align with SMC Engineering,
    - Localization and development of components/parts,
    - Endurance and performance testing of functional parts.
    - FEA using ANSYS Software
    - Evaluation of vehicle to varying climates using Environment Chamber.
    - Fast Fourier Transform Analyzer for measuring vehicle noise and vibration in field use.
    - Seat Pad Accelerometer for evaluating Ride and Comfort level in vehicle.
2. Compliance with Bharat Stage III Emission Norms and other regulations.
    - Engine Matching completed on Engine dynamometers using Emission Analyzers.
    - Emission Matching on Chassis Dynamometer, Drivability/High temperature testing on Performance Chassis dynamometer and Evaporative related Emission Testing to achieve targets set for meeting Euro III Emission Norms. This was done using the ECU matching tools received from ECU makers.
3. Headlamp leveling devices.
4. Compliance Cost reduction by undertaking aggressive VA/VE activities
5. Development of alternate fuel (LPG) variants of Zen. Esteem and Omni Cargo.

Benefits derived as a result of above technology adoptions:

1. Launch of Zen Minor.
2. Launch of Omni Cargo LPG.
3. Launch of standard variants of Versa, Alto and Baleno Sedan.

4. Launch of Zen 3 door.
5. Alto Export model for GCC.
6. Upgradation of Baleno Altura, Alto (Export model) and Wagon R,

Technology adaptations efforts

1. Localization, development and testing of parts for existing and new models.
2. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization.
3. Capabilities being further strengthened in area of alternative fuels like Diesel, CNG and LPG.
4. VA/VE at the time of design and localization to maximize cost benefit.
5. Energy in air washers reduced by optimization of blower speed by using optimum size of pulleys.
6. Compressed air supply temperature optimized to save energy.
7. Motion sensors used to switch On / Off lights in common areas.
8. Invertors used for equipment with varying output.
9. Exhaust fans replaced with energy-less wind ventilator in utilities and other buildings.
10. The cooling tower of compressed air conditioning plant replaced by air cooled system to save water, and provided with microprocessor control.
11. The compressed air supply pressure reduced in some shops, high pressure supply maintained only for a few machines in these shops.

Benefits derived as a result of abort efforts:

1. Indigenization of various vehicle aggregates at lower costs.
2. Improvement and upgradation of existing models for improved comfort, style and better value for money.
3. Continuous reduction in product cost through VA/VE
4. Compliance with new environment related regulations.
5. Reduction of per vehicle consumption of various resources over the last year, electricity by 10.8%, gas by 8%, water by 15.6% and compressed air by 7%.

New technologies were adopted in following areas during year 2004-05:

1. Building Major Change Capability
    - Facility and skill enhancement in styling concept generation and model making.
    - 3D modeling of automotive components using iMan server and UG NX2 workstation.
    - Virtual Simulation analysis of vehicle and components using computer aided engineering (CAE)
    - Upgradation of satellite link between MUL and SMC for improved data flow.
    - Setting up of Client for on-line advance viewing of SMC engineering changes.
    - Measuring and analysis of strain data for vehicle strength analysis using Data Acquisition System.
    - Strengthening of mass emission testing facilities for emission related development.
    - Calibration of engine electronic control module on test bench using AC Dynamometer.
    - VTVV SHED for testing evaporative emission of vehicles.
    - Head form test facility for testing interior components, steering wheel, head restraint and other interior fittings.
    - Seat belt anchorage test facility for testing static strength of seat belt anchorage.
    - Endurance and performance testing of functional parts.
2. Compliance with Bharat Stage III Emission norm and other regulations
3. Headlamps with leveling device for all MUL models
4. Upgradation of Omni brake system to booster assisted type one
5. Sheet metal exhaust manifold
6. Noise and vibration reduction
7. Seat belts with pre-tensioner and force limiter
8. Cable type gearshift control
9. Body Control Module for wiring

Benefits derived as a result of above technology adoptions:

1. Launch of Bharat Stage III variants of all MUL models.
2. Introduction of Headlamps with leveling device in all MUL models.
3. Launch of Esteem with facelift.
4. Launch of Maruti 800 with facelift
5. Launch of Omni with facelift
6. Fitment of speed limiting device in Omni Cargo
7. Launch of Wagon R with ABS and Air Bags
8. Alto Export model for Chile.

Technology adaptations efforts

1. Localization, development and testing of parts for existing and new models.
2. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization.
3. Capabilities being further strengthened in area of alternative fuels like Diesel, CNG and LPG.
4. VA –VE at time of design and localization to maximize cost benefit.
5. For generation of electricity steam and to meet process fuel requirement, Naphtha and LPG replaced by lower cost fuel LNG (Liquefied Natural gas).
6. Air washer water spray pump operation logic modified to reduce electricity consumption.
7. Inlet guide vanes provided in air compressors.
8. An extra burner added in Waste Heat Recovery Boiler to reduce the gas consumption for production of steam.
9. Steam pipe line insulation improved to avoid heat losses and to reduce steam consumption.
10. The water cooled condenser of compressed air conditioning plant replaced by air cooled system to save water.
11. Steam temperature increased to reduce condensation losses.
12. Compressed air pressure reduction in many areas, high pressure supply only to certain machines.

13. Remote operation for auto shut-off valves of compressed air line to minimize the leakage losses.

Benefits derived as a result of above efforts:

1. Indigenization of various vehicle aggregates at lower costs.
2. Improvement and upgradation of existing models for improved comfort, style and better value for money.
3. Continuous reduction in product cost through VA/VE.
4. Compliance to new regulations.

New technologies were adopted in following areas during year 2005-06:

1. 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.
    - Emission testing (Diesel).
    - ECU calibration and performance improvement.
    - Tuning of suspension RHB and EPS.
    - Full vehicle NVH testing.
    - Bumper - Pendulum testing for meeting Indian and GCC countries regulations.
    - Airflow check for engine and A/C performance and engine cooling.
    - Durability testing of diesel vehicle and engine.
    - External and internal parts safety and strength testing.
    - Auto AC evaluation and duct development.
    - High temperature and low temperature testing of vehicle systems.
    - Structural vibration analysis.
    - Motoring and Friction Test bench, thermal shock rig and 2 EC Dynamos setup for engine and emission testing.
    - Synchromesh/slant tester for transmission evaluation.
    - Hydraulic actuators - 16 channel analyzer for strength and safety evaluation.

- PLM to manage CAD, CAM and CAE data for in-house and also to collaborate with SMC and suppliers.
- DMU (virtual design review).

2. Interior fittings testing facility.
3. Design capability for components/systems forVA/VE.
4. Alternate Fuel LPG system meeting BS3 on carburetor engine.
5. Alternate Fuel LPG system for MPI engine.
6. Body control module for wiring
7. Auto AC
8. Air bags and control module
9. ABS

Benefits derived as a result of above technology adoptions:

1. Launch of Swift.
2. Launch of WagonR Primea.
3. Launch of Omni LPG BS3.
4. Launch of Alto with facelift.
5. Compliance with interior fitting regulation.

Technology adaptations efforts

1. Localization, development and testing of parts for existing and new models.
2. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization.
3. Capabilities being further strengthened in area of alternative fuels like Diesel, CNG and LPG.
4. VA –VE at time of design and localization to maximize cost benefit.
5. Inlet air cooling provision made in one of the gas turbines for reducing the fuel consumption and energy cost.
6. Magnetic fuel savers have been provided in the burners of paint baking ovens for reducing the fuel consumption.
7. Increased use of heat of waste gases (steam turbine driven air compressor).

8. Commonization of pumps for better electrical efficiency.
9. Provision of inlet guide vanes in air compressors.
10. Reduction in lighting voltage.
11. Compressed air pressure reduction at various places.
12. Low volume compressed air nozzles in various equipment.
13. New energy management software for compressed air plant.
14. Water quality optimization in various processes.
15. Just in time supply of water/ air/ electricity in various processes.

Benefits derived as a result of above efforts:

1. Company re-certified ISO 14001 as per 2004 standards for the next 3 years.
2. Haryana State Pollution Board granted consent to the company to operate for next 5 years.
3. Indigenization of various vehicle aggregates at lower costs.
4. Improvement and upgradation of existing models for improved comfort, style and better value for money.
5. Continuous reduction in product cost through VA/VE.
6. Compliance to new regulations.

New technologies were adopted in following areas during year 2006-07:

1. 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.
    - Emission testing and emission reduction.
    - ECU calibration and engine performance improvement.
    - Tuning of suspension, RHB and EPS.
    - Full vehicle NVH testing.
    - Durability testing of vehicle and engine.
    - External and Internal parts safety and strength testing.
    - AC system evaluation and development.

- High temperature and low temperature testing of vehicle systems.
- Structural vibration analysis.
- Transmission evaluation using synchromesh/ slant tester.
- Vehicle strength and durability evaluation using hydraulic actuators and data acquisition system.
- PLM to manage CAD, CAM and CAE data for in-house and also to collaborate with SMC and suppliers.
- Digital Mock-up (Virtual design review).
- Virtual vehicle testing for strength, durability and safety.

2. Design capability for components/systems for VA/VE.
3. Alternate Fuel LPG: Development of LPG system for MPI engine.
4. BS3 compliant LPG system for MPI engines
5. Hydraulic clutch
6. Drive by wire accelerator

Benefits derived as a result of above technology adoptions:

1. Launch of Swift Diesel.
2. Launch of Zen Estilo.
3. Launch of WagonR with facelift.
4. Launch of WagonR Duo (LPG).
5. Launch of Alto X fun.
6. Launch of immobilizer equipped models.
7. Launch of Alto 800 LHD in overseas market.
8. Launch of Alto 1.1 Automatic in overseas market.
9. Launch of Zen Estilo in Indonesia.

Technology adaptations efforts

1. Localization, development and testing of parts for existing and new models.
2. Capabilities strengthened in component and vehicle evaluation, benchmarking and design optimization.
3. Capabilities being further strengthened in areas of alternative fuels like Diesel, CNG and LPG.

4. VA/VE at the time of design and localization to maximize cost benefit.
5. Acquisition of design and cost knowledge through tear-down and benchmarking.
6. Improvement in overall efficiency of plant by increased use of waste heat through maximizing running of steam driven compressor by installing steam condenser.
7. Fibre Reinforced Plastic fan blades provided in place of Aluminum fan blades in cooling tower and cooling water modules.
8. Variable speed drives used for different applications.
9. Energy efficient motors installed in place of conventional type to reduce energy consumption.
10. Microprocessor based pressure optimizer installed for optimizing air consumption.
11. Solar energy utilized for heating water in security barracks.
12. Natural lighting provided additionally at new locations.
13. Lighting voltage optimized at various shop levels.
14. Energy-efficient type spares installed in Gas Turbine Power generation unit to reduce gas consumption

Benefits derived as a result of abort efforts:

1. Indigenization of various vehicle aggregates at lower costs.
2. Improvement and upgradation of existing models for improved comfort, style and better value for money.
3. Continuous reduction in product cost through VA/VE.
4. Compliance with new regulations.
5. Significant cost reduction of new model parts compared to existing models, ensuring profitability of new models from day one.
6. Launching of new models with high localization, e.g. Zen Estilo - 94.2%.
7. Significant cost reduction obtained in existing models.
8. Successful ISO-14001 surveillance audit by AV Belgium
9. Reduction in consumption of utilities per car e.g. electricity by 2.5%, air by 1.8%, water by 4.0%, steam by 4.5% and gas by 2.2%.

5.2.5 SWOT analysis

SWOT analysis of MSIL has been carried out as shown in table 5.3.

Table 5.3 SWOT analysis: Maruti Suzuki India Limited

Strengths	***Weaknesses***
• Full technological support from SMC • Japanese philosophy of manufacturing. • In house R and 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 • Brand strength. • 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. • Lack of experience in diesel engine technology. • Indian road conditions not favorable, particularly in rural areas. • Rules and regulation related to tax structure not favorable. • Location of manufacturing facilities in North India, adds significantly to transportation cost for sale in other parts of country.
Opportunities	***Threats***
• 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 providers. • Export avenues in the neighboring countries. • Developing new vehicles using alternative fuels such as CNG, LPG, etc. • Potential business by "True Value" program dealing with preowned cars. • Growing need of fleet for corporate houses through N2N fleet management program. • New avenues with Maruti finance and Maruti insurance. • Maruti Genuine Spares and Maruti Genuine Accessories provide wide business opportunity • Focused marketing efforts. • Easy availability of finance for customers. • Extensive use of VA/VE to reduce cost, improvements in yield, productivity and quality. • Improved material to net sales ratio.	• Growing competition in the market after entry of many MNCs 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 petroleum in the world. • Excessive dependence on the local vendors for component supplies. • A large unorganized sector producing non-genuine spares parts for Maruti vehicles • Movements in commodity prices related to ferro alloys, non-ferro alloys, plastics, rubber and precious metals. • Retaining the trained manpower. • Fluctuation in foreign exchange rates.

5.2.6 Current status of technology adoption

The most important objectives of Maruti Suzuki India Limited for adoption and adaptation of new technologies and building technological capabilities are: (a) improved product quality, (b) improved productivity and (c) increased competitiveness. The company's prime focus is keeping its product quality at the top, while being competitive in the market. Salient features describing the status of technology adoption and adaptation, and technological capability of MSIL presented below:

MSIL is not located in the cluster of similar industries. Rather it has developed vendors around it so as to minimize the transport costs and risks. It is located considerably near a metropolitan city, thus it does not face any problems regarding infrastructural facilities or labor scarcity. It exports products to international markets, thus advanced technology is the lifeline of MSIL. Its products meet international requirements, which are very stringent with regard to reliability, safety and pollution control. It also strongly participates in inter-company groups and networks consisting of other Original Equipment Manufacturers (its partners) as well as its vendors. MSIL even helps its vendors in product development, adoption and adaptation of advanced technologies and building technological capabilities.

MSIL works on Japanese concepts and does not believe in rework and remanufacturing. Quality standards and procedures are followed both in letter and spirit. It seeks advice to a large extent from its customers in order to improve its products.

The company does not avail any assistance from Government's R&D organizations; rather it has accumulated capabilities to reengineer its manufacturing process.

In order to meet market requirement, the MSIL has always been adopting new technologies to keep its products abreast with those of international competitors. At present, the company is using advanced technology for its products. The company adopts new technology immediately on its availability. It considers to a large extent those alternate processes that can be developed in-house for making new technology cost-effective. The company adopts new technology covering all processes and operations. MSIL does extensive analyses based on past trends before going in for new technology. It also carries out economic viability studies for adopting new technology and analyses quantitative and qualitative effects in detail. Before adopting new technology, it also considers consequential changes in related products and processes and plans alternatives for these in detail. The company involves its manpower from the very beginning for adopting new technologies.

At MSIL, the officials frequently visit foreign locations to get new ideas to develop new technologies in house. The role of government in technology adoption is not encouraging. Government does not provide any incentives or other benefits for adopting new technology. However for complying with government regulations (related to pollution control: Euro/BS-II, III etc.), the company has to go for new technology adoptions.

Globalization plays a vital role in MSIL's endeavor to upkeep its technology to the latest available. Opportunities created due to globalization in form of vast markets lead MSIL to produce world class product using most advanced technologies. Similarly, the threats caused by globalization in the form of big competitors in domestic market force MSIL to keep its technology and product quality at the top. Availability of better technology due to globalization has significantly assisted MSIL in new technology adoption.

Top management support has always been a key factor responsible for new technology adoption. Its top management is always ready for taking short-term risks for long-term improvements and allocates sufficient funds for new technology adoption.

Its manufacturing strategy specifically addresses the issue of requirements for continuous technology upgradation. Benefits of new technology are communicated to all the concerned personnel, which helps in its easy adoption. The objectives of new technology adoption are well defined and this assists in its successful adoption.

In house engineers actively participate in technology upgradations, thereby playing a positive role in new technology adoption.

MSIL has very cordial relationships with the suppliers of new technology, thus facilitating its successful adoption. Further, these suppliers of new technology are selected after a thorough and extensive evaluation process. This selection process positively affects the new technology adoption.

Attitude of employees is aligned towards the objectives of new technology adoption and this significantly helps in its easy adoption. Formal education and training programmes are developed for all classes of employees ranging from top management to shop floor controllers.

MSIL has well laid out new technology adoption polices. These policies are extensively and thoroughly used, and these include training of the employees at all levels. These policies are updated and reviewed periodically, and also track technology adoption costs. These policies also help in technological capability building of the MSIL.

Among barriers to technology adoption faced by MSIL, the most severe one are (i) cost of new technology adoption (ii) cost of training and education, (iii) likely obsolescence of technology and (iv) skill deficiency for new technology.

The MSIL faced a few problems when it brought new technologies in contact with old technologies. Severity-wise their problems include (i) difficulty in operating and maintaining new technology and (ii) lack of co-operation and understanding to a considerable extent, besides (iii) lack of knowledge about the new technology to some extent.

Overall the MSIL is fully satisfied with the results achieved after the adoption of new technology.

5.2.7 Current status of technology adaptation

For adapting new technology, MSIL has to redesign its production system to some extent to achieve satisfactory ergonomic and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and smooth flow of material.

For adapting new technology, MSIL redesigns its organizational structure to some extent. People are shifted to some extent within the company. Some suitable persons are recruited from outside. Training is imparted to all concerned personnel to a large extent. Some new methods are devised for performance and efficiency measurement. It also puts in some efforts to make new technology acceptable to employees.

MSIL has not availed any support from governments for technology adaptation. Its top management always provides full support and sufficient for technology adaptation initiatives. It is always ready for taking short term risks in order to derive long term benefits from technology adaptation.

Overall education level of its employees is quite high, which facilitates the process of technology adaptation. Further, this company has a lot of skilled workers which makes the process of technology adaptation much easier, as compared to one having unskilled workers. The technocratization of MSIL is very high and it is one of the key factors responsible for successful adaptation of new technology. Its in-house R&D is very strong and is very helpful in smooth adaptation of new technology. People at MSIL are usually willing to accept changes. It also has well defined technology adaptation policies, which are thoroughly and extensively used. These policies include the training requirements of all concerned employees, procedures and practices for smooth adaptation of new technology. These policies are updated and reviewed regularly and are helpful in building technological capabilities of MSIL. At MSIL, the effectiveness of technology adaptation has increased to a considerable extent by empowerment, extensive training, open communication within the organization, job security, and a system of rewards and recognitions. Adverse effect on work flow and incompatibility of equipment are the significant barriers to technology adaptations at MSIL.

Overall, the MSIL is fully satisfied with the results achieved after the adaptations of new technology.

5.2.8 Technological capabilities

MSIL is well aware of the technologies most important to its business. Technology plays an important role in its business strategy.

The company is well equipped to assess opportunities and threats of technology. It has special technological strengths that it exploits to a large extent. The company knows very well which technology to outsource and which to develop in house.

The management of MSIL has a well developed technology vision. It is fully skilled at formulating the technology strategies to meet business goals and knows main technology priorities.

MSIL possesses full capability to select the technologies needed for its business and is well aware of the best sources for acquiring it. It is effective at acquiring technology and maintaining good links with important external suppliers of technology. Further the technological activities like engineering and R&D are well organized within MSIL. The company has well developed processes for carrying out technology projects and a good system for assessing these. It carries out post project reviews as well. The company is able to learn from one technology project to another.

Govt. policies have no motivational role to play in MSIL's endeavor to invest in new technology whereas regulations related to pollution control require it to upgrade technology. MSIL use external organizations (consultancy firms) to assist in technology assessment. MSIL does not use outside bodies to help it in developing new technology or in implementing its technology strategy. Further it does not work with universities and government R&D organizations for its key technology projects.

MSIL has developed acquiring capability to a considerable extent and is in a position to:

- justify and specify clearly the technologies to be bought based on detailed engineering studies and translation of basic process parameters into layout, plant and equipment;
- identify suitable sellers of technology;
- carry out sound technology, strategic and resource fit assessments;
- identify the most suitable mechanism(s) for buying technology;
- negotiate effective terms for transaction of the technology;
- identify funding sources and obtain funds at competitive rates for expansion and growth; and
- effectively access necessary material inputs for production and is efficiently undertaking project planning and execution.

The company has developed modifying capability to a large extent. Therefore, it can:

- duplicate acquired machinery and equipment parts requiring replacement;
- adapt installed technology and system components for better efficiency;
- carry out minor, incremental improvements for superior quality outputs;
- implement human resources development programs for all activities;
- introduce advanced management techniques for effective performance; and
- prepare production system expansion programmes and implement it properly.

The company has also developed transforming capabilities to a large extent. Therefore, it can:

- effectively utilizing available plant and equipment, planning and controlling production operations;
- carrying out troubleshooting and good predictive, preventive and emergency (breakdown) maintenance;
- quickly changing over to new models; and
- using computerized information and control systems to provide information support and networking for production operations.

The company has built up vending capabilities to a large extent so it is:

- selling outputs for optimum use of resources and production capacity;
- monitoring external situation and evaluating performance;
- identifying new markets and promoting sales of new products in new markets and providing after-sales services to enhance perceived customer satisfaction.

The company has also developed innovating capabilities to a large extent. It can:

- easily reverse engineer acquired technology;
- carry out product and process innovations;
- introduce application and system innovations; and
- introduce core competence leveraging innovations.

Technological capabilities of MSIL have been graphically shown as a radar chart in figure 5.2.

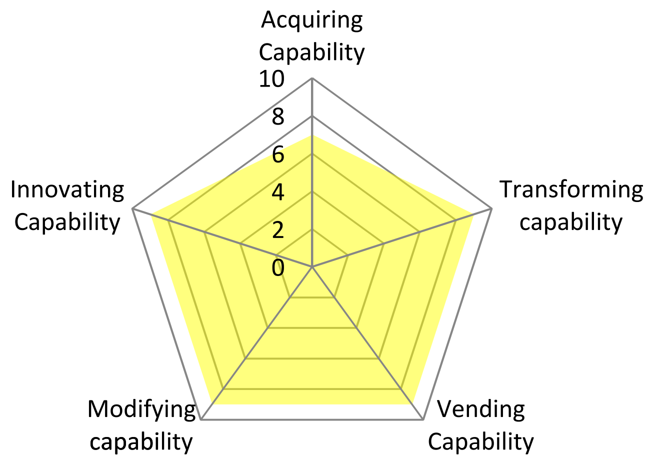

Figure 5.2 Technological capabilities of Maruti Suzuki India Ltd.

In totality, the technological capability of MSIL is categorized as Creative as discussed in Chapter IV. That means MSIL 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.

5.2.9 SAP analysis

Based on the above mentioned current practices in the process of technology adoption and adaptation and technological capabilities in MSIL, its Situation-Actor-Process (SAP) analysis has been done.

Situation

- MSIL obtained its technology from Suzuki Motors Company (SMC) of Japan.
- The company is manufacturing a large variety of cars and utility vehicles to suit various segments of the society.
- Many MNCs have entered in the Indian automobile market manufacturing vehicles employing advanced technology and offering various models/variants at competitive prices.
- Use of advance technology is prevalent
- MSIL noticed stagnation in its market share in last few years.
- Leadership in technology, innovation and R&D for increased localization.
- 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.
- High cost of new technology, high cost of training and likely obsolescence of technology are the biggest barriers to new technology adoption.
- The company faces the problems like fear of layoff among work force, resistance to change and difficulty in operating and maintaining new technology when old and new technologies are brought into contact.
- Adverse effect on work flow and incompatibility of equipment are the significant barriers to technology adaptations.
- The company is fully satisfied with its technology adoption and adaptation practices.

- The company has ability to plan and manage technical changes effectively and efficiently
- The company is well aware of technology issues and the need to acquire technologies.
- The company has the capability to seek out and identify technologies to solve particular problems.
- The company has ability to assess and select cost effective technology solutions.

Actors

- Chairman Board of Directors as the key policy maker.
- Managing Director to manage day-to-day operational affairs.
- Participation of all the employees in organizational goals and objectives by Kaizen teams and suggestion scheme.
- Vendors to MSIL for their suggestions and participation in cost saving and other improvements
- All the customers for their feedback and suggestions

Process

Technology Adoption Aspects

- Continuous updation of new technology covering all areas.
- Optimal use of local manufacturing facilities, skill and raw material.
- Reducing the product development time through digital mockup technology.
- 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.
- Cost reduction by reducing waste, minimizing down time and increasing OEE.
- Following a systematic approach for new technology adoption.
- Involving manpower in process of technology adoption.
- Extensively using in-house capabilities for making new technology cost-effective
- Officials visit foreign countries to get new ideas to develop new technology in-house.

- Well defined technology adoption policies help in building technological capabilities.

Technology Adaptation Aspects

- 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.
- Depending upon the requirements, the company also redesigns its organizational structure. The people are shifted within or are recruited from outside to some extent.
- Extensive training is imparted to employees.
- The top management provides full support for technology adaptation activities.
- Skilled workers easily adapt to new technologies.
- The company has well defined technology adaptation polices which are thoroughly used and regularly updated.
- The effectiveness of adaptation is increased by empowerment, extensive training, job security and rewards and recognition.

Technological Capability Aspects

- The company develops a technology strategy, which includes a framework with priorities and an action plan.
- The company is acquiring, developing and absorbing all necessary technologies.
- The company is successfully implementing the new technologies in various areas.
- The company is learning and accumulating experience in order to continuously improve technological capabilities.
- The company is building core capabilities in few 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 technology.

5.2.10 Learning issues

Based on the detailed study and analysis of the initiatives taken by MSIL to build its technological capabilities; to achieve flexibility, high quality, cost reduction and productivity through flexible management of technology adoption and adaptation, the following issues have emerged.

Main objectives of the company for adoption and adaptation of new technologies have been to increase its product quality, productivity, and competitiveness. The company has achieved its above objectives to a large extent, and 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 parent company Suzuki Motor Company, Japan helps it in capturing a large market share. Its officials visit foreign countries to get new ideas to develop new technologies in-house. The company has developed / acquired new technologies for covering all processes and operations of the company.

Advanced manufacturing technologies (AMTs) have always played a vital role in its success. Systematic, timely and planned use of AMT has helped the company to achieve its business objectives. Adoption, adaptation and further development of technology – through local R&D efforts – has helped it to reduce the cost of their products. It lays considerable emphasis on VA/VE to cut down costs. Use of ICT enabled systems helped it to reduce the inventory level, build technological capabilities, control waste and improve employee relations. It is working towards localization, development and testing of products - both new and existing. This has helped it in indigenization of various vehicle aggregates at lower costs.

In house R&D has helped the company in indigenously developing robots that indicate the accumulation of technological capabilities. It has increased plant capacity by robots and automation so as to reduce cycle time. The company has strengthened its capabilities in component and vehicle evaluation, benchmarking and design optimization that would help it further improve and upgrade its existing models for comfort, style and value for money.

Technology adoption

It has always adopted new technologies immediately on its availability to match the market requirements and considered alternate processes that can be developed in-house for making new technology cost effective. The company also conducts extensive analyses based on the past trends, and studies economic viability for its quantitative and qualitative effects, before going in for new technology. It also considers consequential changes in related products and processes and plans alternatives in detail.

Though there is no government encouragement to adopt new technologies directly or through its industry policies, yet its regulations related to environment, pollution control and safety have forced the company to adopt new technologies from time-to-time. Opportunities or threats caused due to globalization necessitate adoption of new technologies in the company, and easy availability of new technology – due to globalization – is also a very significant factor for its new technology adoption.

Top management fully supports new technology adoption in the company. Formal manufacturing strategies of the company adequately address its new technology adoption needs. Its technology adoption policies include training of the employees at all levels and are updated regularly. Human factor plays a crucial role in its new technology adoption. The company lays stress on employing formally qualified and skilled personnel. It provides training to all levels of its employees and involves them in the process of new technology adoption from its very beginning. In-house engineers actively participate in new technology adoption.

Technology adaptation

For adapting new technology, there is some need of redesigning production systems in the company to carry out ergonomic and safe layout of machines, standardize equipment, use controls and instrumentation effectively, and to ensure smooth flow of materials. Besides need for redesigning production systems in the company, there is some need of redesigning its organization structure; a considerable need of imparting training to its personnel and a similar need for designing new methods for measurement of their performance and efficiency. It makes some efforts to make new technology acceptable to employees, and brings out some changes in manufacturing; product design and features, plans and procedures and reliability have to be implemented during technology adaptations.

Top management of the company provides good support for technology adaptation and allocates sufficient funds for it. Top management takes short-term risks for getting long-term benefits. Availability of more skilled workers – than unskilled ones – in the company helps it in easy adaptation of new technology. Technocratization of the company is a key factor responsible for its successful technology adaptation. Its employees willingly accept changes in technology. The company gives considerable importance to in-house R&D for new technology adaptation, though there are no well laid technology adaptation policies.

Technological capabilities

The company has the ability to plan and manage technological changes efficiently and effectively, and is well aware of technology issues and the need to acquire technologies. It also has the capability to seek out and identify technologies to solve particular problems. It has the ability to assess and select cost effective technology solutions. It has developed its technology strategy, which includes a priority framework and an action plan.

The company is actively engaged in acquiring, developing and absorbing all necessary technologies, and is successfully implementing these new technologies in various areas. It is learning and accumulating experience in order to continuously improve technological capabilities. It is also building core capabilities in some critical areas and exploiting these to the maximum extent possible. It is forming and exploiting linkages with networks of technology suppliers and others involved in technology.

5.2.11 Action suggested

- Employ value analysis and value engineering further for even higher level of flexibility in technology adaptation.
- Increase its technological capabilities further to have a bigger share of export market through products that match global quality benchmarks.

5.2.12 Performance expected

- Retain and increase its domestic market share
- Develop as Asian regional hub for new car development and testing.

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 years. 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.

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, SKSSL continues to adopt lean manufacturing techniques and Toyota Production Systems, and believes in fully utilizing its existing assets.

The company'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.

5.3.1 Company's competitive strategy

Sona Koyo is the largest supplier of steering systems to passenger vehicle manufacturers in the country. It is a tier-I vendor of steering systems and many other components to various automobile OEM such as Maruti Suzuki India Limited, Hyundai Motors, Mahindra and Mahindra, Eicher Tractors and Telco. While the company intends to maintain its dominant position in the domestic market, it has identified exports as a thrust area and has targeted 35% of its revenues to achieve 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 company envisions becoming a world-class quality supplier of auto components. For realizing its vision, it identified world leaders in technology and formed strategic alliances with them. SKSSL benefits from the identified leading companies in technology as well as management and production techniques. A technical centre is being developed in Gurgaon for development purposes. Its suppliers are also instructed and aided in upgrading their quality and in adopting modern production techniques, by the company's Supplier Quality Assurance (SQA) department. SKSSL improves the quality of its own products by helping its suppliers in upgrading their quality and production and management techniques.

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

The company recognized that building sufficient capacity is the key to attaining the next level of growth. The focus was also to become a full service supplier in addition to manufacturing, where company provides a complete suite of services, on turn-key basis, ranging from product designing to manufacturing and further testing and validation. In order to build these capabilities, company has worked on creating a complete back-office engineering support base for developing global manufacturing capacities, improving internal efficiencies and investing in technology infrastructure.

The company strategy is to continuously improve its 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 upgradation of processes within the organization. There are still a few areas where company needs substantive improvements. Detailed road maps have been prepared for carrying out upgradations and these are under implementation.

A chronology of milestones achieved by SKSSL are delineated and presented in the Table 5.5.

Table 5.4 Milestones of Sona Koyo Steering Systems Limited

Jan-1985	Technical Agreement with Koyo of Japan for Manual Steering Gear and Column.
Feb-1986	Sona Steering entered a Joint Venture agreement with Maruti Udyog Ltd.
Oct-1987	Sona Steering Systems Ltd. commenced production.
May-1988	Sona Steering Systems Ltd., a JV with Maruti, listed through an IPO.
Jul-1992	Koyo acquired 8% stake in Sona Steering Ltd.
Aug-1994	Sona Steering certified as an approved vendor to Koyo.
Sep-1994	Incorporation of Mahindra Sona Ltd..
Mar-1995	Mahindra Sona acquired the MSL Division of M&M.
Jul-1995	Technical collaboration with Koyo for Power Steering Gear.
May-1997	Koyo increased stake to 20.5%.
Nov-1997	Sona Cold Forgings commenced productions.

Oct-1998	Sona Steering name changed to Sona Koyo Steering Systems Ltd.
Nov-1998	Sona Okegawa commenced production of bevel gears for domestic market and exports.
Jan-1999	Major exports to USA begin for Mahindra Sona Ltd.
Nov-2003	Sona Koyo received Deming Quality Award.
Sept-2004	Sona Koyo inaugurated 100% EOU in Chennai.
Nov-2004	Acquired 21% stake in Fuji Autotech France S.A.S.
Nov-2005	Received Frost and Sullivan Manufacturing Excellence Award
Apr-2007	Established plant at Dharuhera near Gurgaon
May-2007	Received Teri Corporate Environmental Excellence Award

5.3.2 Performance indicators

The Government of India in its Automotive Mission Plan, 2006-2016 has outlined a vision for India "to emerge as the global destination of choice for the design and manufacture of automobiles and auto components." India will become a global hub for small cars has also been confirmed by global industry leaders including Osamu Suzuki of Suzuki Motor Company, Rick Wagoner of GM, and Carlos Ghosn of Renault-Nissan. It has been estimated that by 2012, India will export one million cars. International automobile manufacturers are developing next generation global platforms, which will be launched in India at the same time as their global launch. Sona Koyo shares this vision and will be a part of this growth. Indeed, everything that it is doing today, and will be doing in the years to come, is directed to its vision of becoming a global integrated steering solutions provider and the partner of choice to global customers. And as the new generation global car and off-highway platforms come into play, this company will develop new steering systems thereby further enhancing its development capabilities.

The compact car segment, where the company products have a very strong presence, will continue to dominate the domestic market. Trends in steering technology indicate that the proportion of passenger cars in India with electronic power steering would double from present 20% level to 40% by 2012. SKSSL, being a pioneer in the domestic segment for Electronic Power Steering would get the first mover advantage. Further, there is a new class of low-cost entry-level cars and light commercial vehicles that have an extremely good fit with the existing product profile of SKSSL. Thus, the company not only intends to supply overseas markets, but also to 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.

The company is investing in localization projects of both Hydraulic and Electronic Steering Systems to ensure sustained cost competitiveness. All these efforts are based on strong foundation of TQM and TPM principles and its commitment of the company in R&D initiatives. With the increased dependence on virtual prototyping and testing, the cost of making physical prototypes has reduced considerably.

Various performance indicators of the company have been presented in figure 5.2.

Net sales increased by 27.1% 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 growth in sales 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% 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% - 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 showed a continuous growth 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.

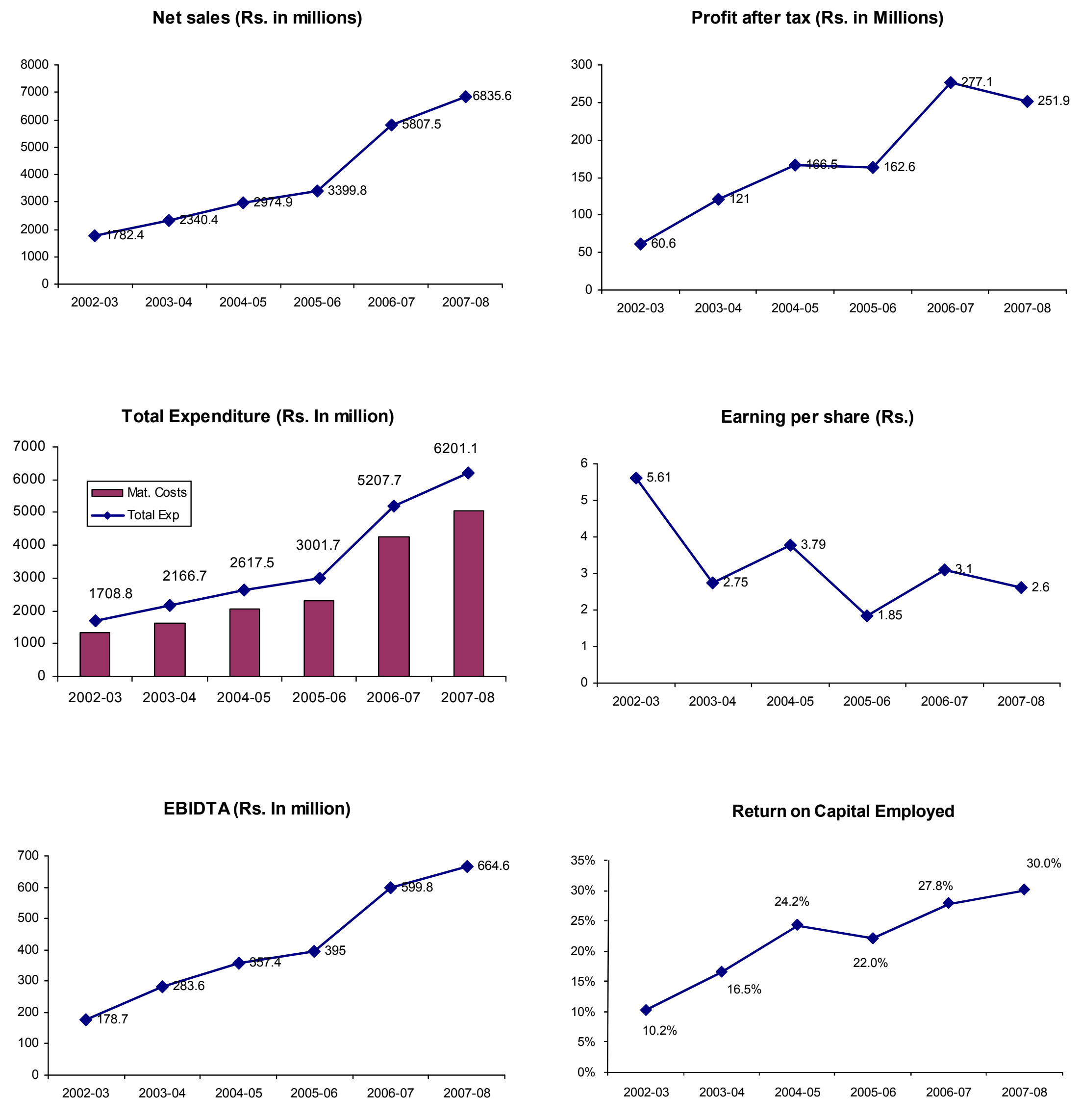

Figure 5.3 Performance indicators of Sona Koyo Steering Systems Limited

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 decreased marginally by 2.4% to Rs. 3.70 for year 2005-06. This year company decided to give one bonus share to its existing shareholders for every share held by them. So, the net EPS worked out to be Rs. 1.85 for the year 2005-06. Further, EPS increased to Rs. 3.1 in 2006-07, but 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 show 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, but rose to 27.8% in 2006-07, and 30% in 2007-08.

5.3.3 Current practices

During 2004-05, most product lines of the company, especially in steering parts operated at full capacity. Consequently, company embarked on a capacity expansion plan. It created global capacities in steering and driveline components and planned to invest Rs 4 billion in a phased manner between April 2006 and March 2010.

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 is also working 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.

The company has aligned and strengthened its geographic presence in the country by setting-up facilities that take into account new projects and capacity expansion plans of various vehicle manufacturers. By doing so, the company has been able to be at close proximity to its customers and to get greater value from its operations. In line with this, Sona Koyo 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 its Chennai plant.

Sona Koyo has also recently entered into a majority owned Joint Venture "Arjan Stampings Private Limited" with Arjan Auto Private Limited to manufacture stamped parts used by customers in Europe for steering columns and seat recliners. This enabled 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 manufacturing, since the export potential of these components is significant.

In the current market scenario, customer expectations on product performance are getting higher. Therefore, there is a constant need to innovate and deliver high quality products. Sona Koyo has always stressed on its quality management initiatives to continuously improve its efficiencies for meeting customers' expectations.

The company started a major initiative called High Volume Production Trial (HVPT). It conducts HVPT before starting production for any new item, with an aim to judge whether or not its mass production can be started. This enables smoother launch of a new product or a new production line. The result of this exercise was seen in terms of the reduction in rejection of new products both in-house and at customer’s end. 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 next activity.

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 its 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 cost continues to follow a decreasing trend primarily on account of internal VA/VE programs and negotiations with the suppliers.

Over the years, ICT has evolved as a key function in supporting SKSSL to meet its organizational goals. It plays an important role in supporting the company's focus on capturing operational efficiencies, interfacing with customers and suppliers and developing new products at low cost thereby building technological capabilities.

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 Windchill – 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. ERP applications allow redefinition of the competitiveness and enhancement in business process performance through the adoption of the best business practices. 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-house coordination. 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 handles 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 in a better way, utilization of IT resources across the company. Currently, all company locations are connected directly by high-speed optical fibre radio frequency 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.

5.3.4 New technology – adoption and adaptation

Having realized the necessity of using technology as a competitive tool, the company has been actively developing its technological capabilities. From being a pure manufacturing organization, the company currently has been actively partnering its customers i.e. OEMs for product development. The company has acquired capabilities to design, develop and test most of its manual steering gears and columns. New products, introduced in past three years, accounted for over 44% of total sales.

SKSSL significantly developed its testing facilities. 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 has improved its market position, and resulted in potential customers choosing the company for their new development programmes.

In line with its vision to become a preferred supplier to global customers, the company continues to pursue its strategic objective of harnessing its technological capabilities. It has 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 adopted technology for electronic power steering systems for passenger cars from its partner, JTEKT, and Steering Column for commercial vehicles from Fuji Autotech AB, Sweden. As a next step, the company worked on increasing localization of these technologies to become more competitive, and enhance its market position.

Regarding in-house technology development, the company is in advanced stages of developing Electric Power Steering for off-highway vehicles for the US market. This is a very competitively priced product and, hence, the future demand is expected to be high. The company has also filed for patents.

In addition, the company has also tied-up with premier research institutions such as IITs at Delhi and Mumbai to develop future technologies in Steering Systems and their components. It has made investments in R&D and has two exciting projects in the pipeline. One is its 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 and currently is self-sufficient in testing hydraulic products. It is now exploring the idea of developing this facility as a testing hub for its global partners.

The company efforts towards technology adoptions and adaptations along with the benefits derived have been summarized below.

New technologies were adopted in following areas during year 2003-04:

1. New mechanism for energy absorption in Column Assemblies and ECU for Electric Power Steering.
2. Test track for on-vehicle tests of Steering Systems
3. New Tilt and Telescopic Column Assembly

Benefits derived as a result of above technology adoptions:

1. New business opportunities in the global and domestic market in tractor and passenger car segments
2. Introduction of new Tilt and Telescopic Column Assembly for European market

Technology adaptations efforts

1. Localization of critical parts of Power Steering.
2. Engineers sent to Koyo Seiko Company, Japan for training on Electric Power Steering.
3. HSD/LDO fuel was substituted by SKO fuel, resulting into fuel cost saving of Rs. 12.20 lakh;

4. Installation of energy saving circuits on Cooling Towers contributed saving of Rs. 2.87 lakh; and
5. Modification of Forced Draft Ventilation contributed a saving of Rs. 2.42 lakh

Benefits derived as a result of above efforts:

1. Import substitution and saving in foreign exchange due to localization.
2. Become more competitive in prices in the global markets due to localization of parts.
3. Savings worth lakh of rupees in terms of energy saved.

New technologies were adopted in following areas during year 2004-05:

1. Virtual simulation and testing of new products before they are released for manufacturing.
2. Electronics Department, for understanding the future trends of Electronics in Steering System.
3. On-vehicle testing capabilities were developed to capture the data of vibration, noise, steering efforts and returnability.

Benefits derived as a result of above technology adoptions:

1. New business opportunities in the global market for off highway vehicles.
2. Better understanding of end customers' requirements due to on-vehicle testing capabilities.
3. Ability to reduce the customer rejections and warranty claims significantly.

Technology adaptations efforts

1. Localization of critical parts of power steering.
2. Engineers sent to Koyo Seiko Co., Ltd., Japan for training on electric power steering.
3. Proper load distribution and effective preventive maintenance of DG Sets.
4. Modification of piping on cooling towers for stopping the operation of 'hot well pumps'.
5. Installation of Energy Saving Circuits on pneumatic gauges.

Benefits derived as a result of above efforts:

1. Import substitution and saving in foreign exchange due to localization.
2. Increased competitiveness in prices in the global markets due to localization of parts.

3. Energy savings worth lakh of rupees in terms of energy saved.

New technologies were adopted in following areas during year 2005-06:

1. High-end tubular technology for Steering Columns
2. Manufacturing facilities for hydraulic power steering valve assemblies
3. Cost effective electric power assist module (E-PAM) for off-highway vehicles.
4. Testing rigs.

Benefits derived as a result of above technology adoptions:

1. Penetration in the global market of steering columns, and export of parts back to other associates across the globe.
2. Reduction in development time for new products.
3. Cost competitiveness
4. Overcome hindrances by gaining technical knowledge from problems faced in technology adoption.
5. Testing capabilities made company self-sufficient for a majority of its testing needs.

Technology adaptations efforts

1. Efficiency improved in compressed air system resulted in saving of Rs. 10.80 lakh.
2. Solar water heating system installed for hot water application, which lead to the saving of Rs. 2.5 lakh.
3. Reduced pumping load from 30 HP to 15 HP in various cooling towers, resulted in saving of Rs. 3.5 lakh.

Benefits derived as a result of above efforts:

1. Import substitution and saving in foreign exchange due to localization.
2. Savings worth lakhs of rupees in terms of energy saved.

New technologies were adopted in following areas during year 2006-07:

1. Company acquired the manufacturing technology for column type electric power steering (C-EPS) from its collaborator, JTEKT Corporation, Japan.
2. Setting up of core manufacturing facilities to manufacture valve assemblies for hydraulic power steering locally using the technology from its collaborator.
3. Advanced featured steering columns for commercial vehicles.

Benefits derived as a result of above technology adoptions:

1. Achieved cost-competitiveness in domestic market through localization of electric power steering.
2. New avenues for supplying parts back to its collaborator.
3. Fulfilled customers' requirements of next generation vehicles.

Technology adaptations efforts

1. Localization of valve assembly for hydraulic power steering gear.
2. Developed an alternate cost effective electric power steering technology for off-high way application completely on its own and submitted its prototype
3. Efficiency improved in compressed air system resulted in saving of Rs. 3.75 lakh.
4. Replaced air-cooled 3000 KVA transformer with 2250 KVA energy efficient transformer resulted in saving of Rs. 32.2 lakh.
5. Installed energy efficient pump in paint shop resulted in saving of Rs. 2.5 lakh.
6. Installed bio gas plant for canteen waste utilization resulted in saving of Rs. 0.75 lakh.
7. Improved FO generator loading efficiency by improving cooling systems resulting in saving to the tune of Rs. 30.2 lakh.

Benefits derived as a result of above efforts:

1. Import substitution as well as reduced time-to-market for new projects.
2. Able to cater to customers' requirement of next generation vehicles
3. Energy savings worth lakh of rupees.

5.3.5 SWOT analysis

On the basis of the case study carried out in SKSSL, a SWOT analysis has been done in which the strengths, weaknesses, opportunities and threats for this company were identified. This SWOT analysis has been summarized in table 5.6.

Table 5.5 SWOT analysis: Sona Koyo Steering Systems Limited

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.	• Main dependence on OEMs. • Adapting to The Indian government rules and regulations. • Costly imported components in the power 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.	
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 particularly 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.

5.3.6 Current status of technology adoption

The most important objectives of Sona Koyo Steering Systems Limited (SKSSL) for adoption and adaptation of new technologies and building technological capabilities are Improved Product Quality, Improved Productivity and Increased Competitiveness. The company’s prime focus is on product quality and while keeping its product quality at the top, it aims to be competitive in the global market.

SKSSL is located in a industrial hub, Gurgaon which is a dense cluster of manufacturing industries. It has also developed its other manufacturing facilities around the OEMs so as to minimize the transport costs and risks. It is located considerably near a metropolitan city, thus it does not face any problems regarding infrastructural facilities or labor scarcity. It exports products to international markets, thus advanced technology is the lifeline of SKSSL. Its products meet international requirements, which are very stringent with regard to reliability and safety. It also strongly participates in inter-company groups and networks consisting of other Original Equipment Manufacturers (its partners) as well as its vendors. SKSSL even helps its vendors in product development, adoption and adaptation of advanced technologies and building technological capabilities.

It strongly participates in groups and networks consisting of its OEMs and vendors. SKSSL even helps its OEMs in product development and testing; and vendors in adoption and adaptation of advanced technologies for building technological capabilities. SKSSL works on Japanese concepts and does not believe in rework and remanufacturing. Quality standards and procedures are followed piously. It considerably seeks advice from its customers in order to improve its products and thus the voice of customers has got a good place in this company.

SKSSL avails assistance from premier educational institutes like IITs in developing new technologies. It possesses enough capabilities to reengineer its manufacturing process.

In order to meet market requirement, the SKSSL have always been adopting new technologies to keep its products shoulder to shoulder with those of international competitors. At present, the company is using advanced technology for its products. The company adopts new technology immediately on its availability. It considerably explores the alternate processes that can be developed in house for making new technology cost effective. The company adopts new technology covering most of the important processes. SKSSL 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 analyzes quantitative and qualitative effects in details. Before adopting new technology, SKSSL considers, in detail, consequential changes in related products and processes and plans alternatives for these. The company involves its manpower from very beginning for adopting new technologies.

At SKSSL, the managers and engineers frequently visit foreign locations to get new ideas to develop new technologies in house. The role of government in technology adoption is not encouraging. Government does not provide any incentives or other benefits for adopting new technology. However for complying with government regulations (related to safety etc.) it has to go for new technology adoptions.

Globalization plays a vital role in SKSSL's endeavor to update its technology to the most modern available. 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. Availability of better technology due to globalization conspicuously assisted SKSSL in new technology adoption.

Top management support has always been a key factor responsible for new technology adoption. Its top management is always ready for taking short-term risks for long-term improvements and allocates sufficient funds for new technology adoption.

Its manufacturing strategy specifically addresses the issue of requirements for continuous technology upgradation. Benefits of new technology are communicated to all the concerned personnel, which helps in its easy adoption. The objectives of new technology adoption are well defined and this assists in its successful adoption.

In house engineers actively participate in technology upgradations, thereby playing a positive role in new technology adoption.

SKSSL has very cordial relationships with the suppliers of new technology, thus facilitating its successful adoption. Further, these suppliers of new technology are selected after a thorough and extensive evaluation process. This selection process positively affects the new technology adoption.

Attitude of employees is aligned towards the objectives of new technology adoption and this significantly helps in its easy adoption. Formal education and training programmes are developed for all classes of employees ranging from top management to shop floor controllers.

SKSSL has well laid out new technology adoption polices. These policies are extensively and thoroughly used, and these include training of the employees at all levels. These policies are updated and reviewed periodically, and also track technology adoption costs. These policies also help in technological capability building of the SKSSL.

Major barriers to technology adoption in SKSSL are (i) cost of training and education, (ii) cost of new technology adoption, and (iii) adverse effect on work flow. The SKSSL faced a few problems when it brought new technologies in contact with old technologies. Severity-wise their problems include (i) difficulty in operating and maintaining new technology and (ii) lack of co-operation and understanding to a considerable extent, besides (iii) lack of knowledge about the new technology to some extent.

Overall the SKSSL is fully satisfied with the results achieved after the adoption of new technology.

5.3.7 Current status of technology adaptation

For adapting new technology, SKSSL has to redesign its production system to some extent to achieve satisfactory ergonomic and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and smooth flow of material.

For adapting new technology, SKSSL redesigns its organizational structure to some extent. People are shifted to some extent within the company. Some suitable persons are recruited from outside. Training is imparted to all concerned personnel to a large extent.

Some new methods are devised for performance and efficiency measurement. It also puts in some efforts to make new technology acceptable to employees.

SKSSL has not availed any support from government for technology adaptation. Its top management always provides full support and sufficient for technology adaptation initiatives. It is always ready for taking short term risks in order to derive long term benefits from technology adaptation.

Overall education level of its employees is quite high, which facilitates the process of technology adaptation. Further, this company has a lot of skilled workers which makes the process of technology adaptation much easier, as compared to one having unskilled workers. The technocratization of SKSSL is very high and it is one of the key factors responsible for successful adaptation of new technology. Its in-house R&D is very strong and is very helpful in smooth adaptation of new technology. People at SKSSL are usually willing to accept changes. It also has well defined technology adaptation policies, which are thoroughly and extensively used. These policies include the training requirements of all concerned employees, procedures and practices for smooth adaptation of new technology. These policies are updated and reviewed regularly and are helpful in building technological capabilities of SKSSL. At SKSSL, the effectiveness of technology adaptation has increased to a considerable extent by empowerment, extensive training, open communication within the organization, job security, and a system of rewards and recognitions. Adverse effect on work flow and incompatibility of equipment are the significant barriers to technology adaptations at SKSSL.

Overall, the SKSSL is fully satisfied with the results achieved after the adaptations of new technology.

SKSSL has well defined technology adaptation policies also, which are thoroughly and extensively used. These policies include the training requirements of all concerned employees and are updated and reviewed regularly. Further these policies include procedures and practices for smooth adaptation of new technology. These policies are helpful in building technological capabilities of SKSSL.

At SKSSL, the effectiveness of technology adaptation is increased to a large extent by empowerment, extensive training, open communication within the organization, job security, rewards and recognitions.

The significant barriers to technology adaptations at SKSSL include incompatible equipment and adverse effect on work flow.

Overall, the SKSSL is fully satisfied with the results achieved after the adaptations of new technology.

5.3.8 Technological capabilities

SKSSL is well aware of the technologies most important to its business. Technology plays an important part is SKSSL's business strategy.

The company is well equipped to assess technology opportunities and can easily assess the technological threats. SKSSL has special technological strengths which it is exploiting to a large extent. The company knows well which technology to outsource and which to develop in house.

The management of SKSSL has a well developed technology vision. It is fully skilled at formulating the technology strategies to meet business goals and knows main technology priorities.

SKSSL possesses full capability to select the technologies needed for its business and is well aware of the best sources for acquiring it. It is effective at acquiring technology and maintaining good links with important external suppliers of technology. Further its technological activities like engineering and R&D are well organized. It has well developed processes for carrying out technology projects and a good system for assessing these. It carries out post project reviews as well. The company is able to learn from one technology project to another.

Government policies have no motivational role to play in SKSSL's endeavor to invest in new technology whereas regulations related to pollution control require it to upgrade technology. SKSSL use external organizations (consultancy firms) to assist in technology assessment. SKSSL collaborates with other organizations to help it in developing new technology, but implements its technology strategy on its own. Further it works with universities and government R&D organizations for its key technology projects.

SKSSL has full capability to select the technology needed for its business and is well aware of the best sources of technology.

SKSSL is very effective at acquiring technology from external sources and maintains good links with important external suppliers of technology. Further the technological activities like engineering and R&D are well organized within SKSSL. 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. The company is able to learn from one technology project to another.

SKSSL has developed acquiring capability to a considerable extent and can easily justify and clearly specify the technologies to be bought based on detailed engineering studies and translation of basic process parameters into layout, plant and equipment; identify suitable sellers of technology and carry out sound technology, strategic and resource fit assessments; identify the most suitable mechanism(s) for buying technology; negotiate effective terms for the transaction of the technology, identify funding sources and obtain funds at competitive rates for expansion and growth, effectively access necessary material inputs for production and is efficiently undertaking project planning and execution.

The company has accumulated modifying capability to a large extent, so it can duplicate acquired machinery and equipment parts requiring replacement; adapt installed technology and system components for better efficiency; carry out minor, incremental improvements for superior quality outputs; implement human resources development programs for all activities, introduce advanced management techniques for effective performance and prepare and implement production system expansion programmes.

The company has also developed transforming capabilities to a large extent so it is effectively utilizing plant and equipment; planning and controlling production operations; carrying out troubleshooting and good predictive, preventive and emergency (breakdown) maintenance; changing over to new models quickly; and providing information support and networking for production operations using computerized information and control systems.

The company has built up vending capabilities to a considerable extent by selling output for optimum use of resources and production capacity; monitoring external situation and evaluating performance; identifying new markets and promoting sales of new products in new markets; and providing after-sales services to enhance perceived customer satisfaction.

The company also possesses innovating capabilities to a considerable extent. It can reverse engineer acquired technology; carry out product and process innovations; and introduce core competence leveraging innovations.

The present status of technological capabilities of SKSSL have been shown in figure 5.4.

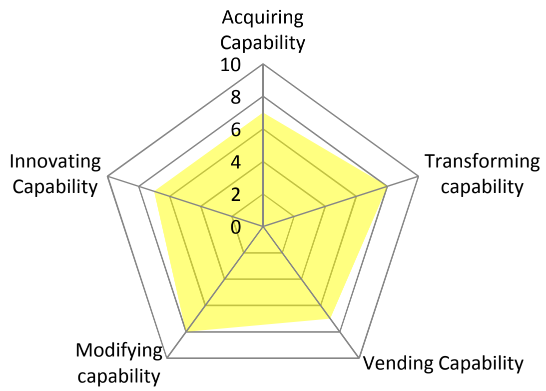

Figure 5.4 Technological capabilities of Sona Koyo Steering Systems Ltd

Thus, the technological capability of SKSSL is categorized as Creative as discussed in chapter IV. The company has a fully-developed set of technological capabilities and is able to define the international technology frontier. In many areas it takes a creative and pro-active approach to exploiting technology for competitive advantage.

5.3.9 SAP analysis

Based on the above current practices in the process of technology adoption and adaptation and technological capabilities, the situation-actor-process (SAP) analysis of SKSSL has been done and presented here.

Situation

- 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.
- It has widened its customer base from MUL to other OEMs also, e.g. Hyundai, Eicher, Telco etc.
- As a tier-1 vendor to OEMs, dealing with tier-2 and tier-3 vendors, it has assured scheduled supply of components to OEMs on JIT, and ERP solutions have improved the systems of the organization and changed the work-culture.
- High cost of new technology, high cost of training and likely obsolescence of technology are the biggest barriers to new technology adoption.

- The company faces the problems like fear of layoff among work force, resistance to change and difficulty in operating and maintaining new technology when old and new technologies are brought into contact.
- Adverse effect on work flow and incompatibility of equipment are the significant barriers to technology adaptations.
- The company is fully satisfied with the technology adoption and adaptation practices.
- The company has ability to plan and manage technical changes effectively and efficiently
- The company is well aware of technology issues and the need to acquire technologies.
- The company has the capability to seek out and identify technologies to solve particular problems.
- The company has ability to assess and select cost effective technology solutions.

Actors

- Managing Director as the key decision-maker.
- Skilled, trained and flexible work force.
- Flexible and sincere managers and supervisors.
- Tier-2, Tier-3 vendors and other suppliers to SKSSL.
- Original Equipment Manufacturers (OEM's) of SKSSL.

Process

Technology Adoption Aspects:

- Technical collaboration with world leaders has helped in manufacturing of world-class products.
- Automation in the production area.
- Increase in the partnership of Koyo Seiko Company Limited Japan.
- Increasing the customer's base and starting manufacturing of steering systems for utility vehicles and LCVs.
- Following a systematic approach for new technology adoption.
- Involving manpower in process of technology adoption.

- Extensively using in-house capabilities for making new technology cost-effective
- The company has well defined technology adoption polices which are thoroughly used and regularly updated.
- Officials visit foreign countries to get new ideas to develop new technology in-house.

Technology Adaptation Aspects

- Optimal use of manufacturing facilities for productivity increase.
- Suitable change in technology for Electronic Steering systems.
- The top management provides full support for technology adaptation activities.
- 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.
- Depending upon the requirements, the company redesigns its organizational structure. The people are shifted within or are recruited from outside.
- Extensive training is imparted to employees.
- Skilled workers easily adapt to new technologies.
- The company has well defined technology adaptation polices which are thoroughly used and regularly updated.
- The effectiveness of adaptation is increased by empowerment, extensive training, job security, and rewards and recognition.
- In-house R&D greatly facilitates the process of technology adaptation.

Technological Capability Aspects

- The company develops a technology strategy, which includes a framework with priorities and an action plan.
- The company is acquiring, developing and absorbing all necessary technologies.
- The company is successfully implementing the new technologies in various areas.
- The company is learning and accumulating experience in order to continuously improve technological capabilities.
- The company is building core capabilities in some critical area and exploiting these to the maximum extent.

- The company is forming and exploiting linkages with networks of technology suppliers and others involved in technology.

5.3.10 Learning issues

Based on the detailed study and analysis of the initiatives taken by SKSSL to build technological capabilities and to attain flexibility, quality, cost reduction and productivity through flexible management of technology adoption and adaptation, the following issues have emerged for learning.

Main objectives of the company for adoption and adaptation of new technologies have been to increase its product quality, productivity, and competitiveness. The company has achieved its above-mentioned objectives to a large extent, and 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 parent company Koyo Seiko Company Ltd helps it in capturing a large market share. Its officials visit foreign countries to get new ideas to develop new technologies in-house.

It has given considerable emphasis to value analysis and value engineering to cut down costs, and is using IT enabled systems in building its technological capabilities. It has been working towards localization, development and testing of its new and existing products - thus attaining a high degree of indigenization of its various products.

Technology adoption

The company has developed / acquired new technologies for covering all processes and operations of the company. It has always adopted new technologies immediately on its availability to match the market requirements and considered alternate processes that can be developed in-house for making new technology cost effective. The company also conducts extensive analyses based on the past trends, and studies economic viability for its quantitative and qualitative effects, before going in for new technology. It also considers consequential changes in related products and processes and plans alternatives in detail.

Opportunities or threats caused due to globalization have necessitated adoption of new technologies in the company. Easy availability of new technology – due to globalization – is also a very significant factor for its new technology adoption. Top management fully supports new technology adoption in the company. Manufacturing strategies of the company address its new technology adoption needs. It has technology adoption policies which include training of the employees at all levels. These policies are updated regularly. Human factor plays a crucial role in its new technology adoption. The company employs formally qualified and skilled personnel. It provides training to all levels of its employees and involves them in the process of new technology adoption from its very beginning. In-house engineers actively participate in new technology adoption.

Technology adaptation

The company adopts new technology from alliance partners. With in-house R&D efforts, it reduces lead-time in new product introduction and its further localization to suit market conditions. It makes minor modifications in both its production system and its organizational structure for enhanced effectiveness of its technology adaptation process.

Top management of the company provides good support for technology adaptation and allocates sufficient funds for it. Top management takes short-term risks for getting long-term benefits. Availability of more skilled workers – than unskilled ones – in the company and technocratization of the company are key factors in its successful technology adaptation. Its employees willingly accept changes in technology. The company gives considerable importance to in-house R&D for new technology adaptation, though there are no well laid technology adaptation policies.

Technological capabilities

The company has the ability to plan and manage technological changes efficiently and effectively, and is well aware of technology issues and the need to acquire technologies. It also has the capability to seek out and identify technologies to solve particular technology problems. It has the ability to assess and select cost effective technology solutions. It has developed its technology strategy that includes a priority framework and an action plan.

The company is actively engaged in acquiring, developing and assimilating all necessary technologies, by implementing these new technologies successfully in various areas. It is learning and accumulating experience in order to continuously improve technological capabilities. It is also building core capabilities in some critical areas and exploiting these to the maximum extent possible. It is forming and exploiting linkages with technology suppliers and joint venture companies.

5.3.11 Actions Suggested

- Increase its customer base, and decrease its dependence on a few big companies as its customers.

- Employ value analysis and value engineering further for even higher level of flexibility in technology adaptation.
- Develop further flexibility in adoption and adaptation for testing facilities.

5.3.12 Performance expected

- Retain and increase its domestic market share and increase its exports.
- Develop as a turn-key supplier for new steering systems.

5.4 MOSERBAER INDIA LIMITED (MIL)

Moser Baer India Limited (Moser Baer / MIL), one of India's leading technology companies, 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 diverse areas of Solar Energy, Home Entertainment, IT Peripherals, and 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, US, 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 of the world's optical media manufacturers and commands a 16% share of global optical media market. 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 in the suburbs of New Delhi. It has over 6,000 full-time employees working 24 hours a day at multiple manufacturing facilities. 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 Company's competitive strategy

Since inception, Moser Baer has always endeavored to create its place in the international market., A carefully planned and sustainable business model - low costs, high margins, high profits, reinvestment and capacity growth has aided the company in its efforts. Along the way, deep relationships have been formed 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 has developed a high level of process capability. 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's high product development competence coupled with adequate level of process and product know-how offers problem-solving competencies. The company carries out research independently and often develops 'base' technologies at its own risk. Moreover, the company even develops new products without a specific problem definition of its OEMs.

A chronology of milestones achieved by MIL is presented in the Table 5.8.

Table 5.6 Milestones of Moserbaer India Limited

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 the 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 and 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. Its articulated vision of 'touching lives through technology products and services' encapsulates its commitment to embrace next generation technology for harnessing immeasurable power of the knowledge capital, thus setting new technology benchmarks. Product wise highlights of the company business strategy and operational objectives have been delineated in the Table 5.9.

Table 5.7 Business Strategy and Objectives of Moserbaer India Limited

Business Strategy		
Optical	***PV business***	***Entertainment***
Short term • Increase global market share to 20% • 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 and asset turnover. • Target "first to market" in near field and holographic technologies. **Long term** • Continue to be the 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 upto the BOS. • 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% 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 channels. **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** • Become leader in creation and distribution of quality content spanning the entire entertainment and infotainment segments.
Operational Objectives		
• Augment technological and cost leadership further. • Scale up the contribution of value-added next generation products and penetrate markets with these products. • Launch new innovative products for customers continuously, 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 reduce cost. • Evolve an effective sourcing strategy. • Execute the projects for new technologies and put 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 both on doing different things as well as doing things differently. The company export close to 85% of total annual 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, during 2006-07, 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.

Net sales: The net sales from operations was 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 areas 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 of the year. 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 positive hues to an otherwise sedate industry environment in the near to medium term. Long term variables still remain healthy as need for storage media and consumer demand continues to grow.

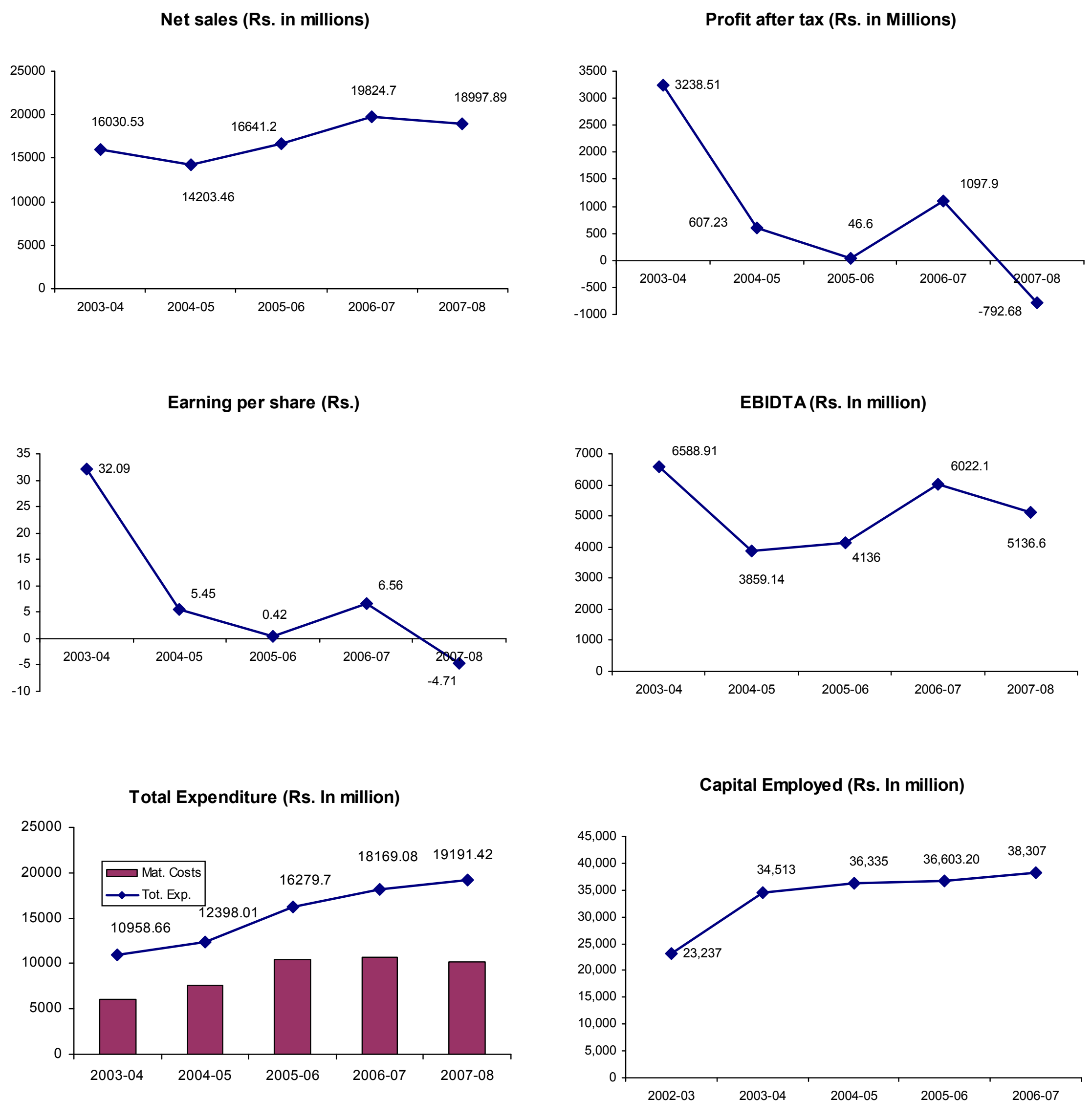

Figure 5.5 Performance indicators of Moserbaer India Limited

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 and 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 ependiture: 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%. 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 Current practices

Moser Baer manufactures products, which leverage its technology development and commercialization strengths to offer the best, value-enhanced and differentiated technology products to its global customer base. Improving operational efficiencies coupled with increasingly efficient and 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 also improve its leadership position within the industry further. In addition, it intends 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 `MoserBaer' 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 local conditions in mind in terms of enhanced durability and resistance to both environmental and human-induced hazards. The company also achieved a unique technology and 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 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. Its 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. The company realized that PV markets have different needs and emerging technologies have to be developed 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. This technology is based on gallium arsenide cells, originally developed for harsh extra-terrestrial solar applications and environments.
- A significant equity stake in Solaria, a US-based technology company that has developed a unique form of low-concentration solar PV technology. It is capable of producing power equivalent to two to three times the power produced by conventional PV modules, using the same amount of silicon material.
- A minority but significant 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 these, 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.

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 will take advantage of Moser Baer's established production capability and a well-developed national distribution network. This business will also act 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 2006-07, 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 enabled the company to revolutionize the quality-price parity and offer unprecedented value for the consumers in Indian market.

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 will leverage its equity and brand image and unveil a product range with medium-to-high end positioning.

As technology playing a bigger role in the company's ability to offer a complete basket of products to its customers, its efforts towards technology adoption and adaptation during recent past has been presented below.

5.4.4 New technology – adoption and adaptation

The company's high technological capabilities coupled with adequate level of process and product know-how offers problem-solving competencies. The company carries out research independently and often develops 'base' technologies at its own risk. Moreover, the company even develops new products without a specific problem definition of its OEMs.

The company is amongst a handful of companies that have tie-ups with leading technology institutes like the Indian Institute of Technology (IIT), Delhi and Banaras Hindu University (BHU), Varanasi. These institutions contain a vast pool of highly talented scientists and with collaborative activities like these breakthroughs in 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, and in the tie-up with BHU, the emphasis will be on alternate materials development.

For the last few years, 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 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.

New technologies were adopted in following areas during year 2003-04

1. Production of high speed CD-R 52X process using alternate dye technologies resulting in significant reduction in cost per CD-R.
2. Production of 4X, 8X DVD-R and 4X DVD + RW processes to keep pace with technology and market trends.
3. Improvement in existing processes to achieve significant improvement in archival life of products.
4. Establishment of highly advanced state of the art Mastering and Galvanics facility. This has further improved overall cost of operation.

New technologies were adopted in following areas during year 2004-05:

1. Production of 16x DVD+R and 16x DVD-R.
2. Production of the world's fastest LightScribe CD-R disk, and a unique process to develop an enhanced DVD-R LightScribe disk.
3. Production of DVD-RW.
4. DVD+R (8x and 16x) and DVD-R (8x and 16x) fully converted to production in 2004-05.
5. DVD+RW (4x) and DVD-RW (4x) fully converted to production in 2004-05.
6. High archival-grade disk using unique dye technology.

Technology adaptations efforts

1. Commissioning of steam-based vapor absorption systems, which effectively recycle exhaust gases from the company's power plants.
2. Commissioning of hot water vapor absorption system was commissioned to utilize the heat of the generating set to produce chilled water.

3. Development of a new production process having wider process windows than its earlier process. This enabled reduction in the level of conditioning needed in coating areas and reducing energy consumption.

New technologies were adopted in following areas during year 2005-06:

1. BDRE (Rewritable) high density optical media format.
2. Patented BD-R L2H inorganic write once discs.
3. HD DVD Single layer and double layer media.
4. DVD+R 16X media.
5. Professional archival CD and DVD media.
6. DVD+RW 8x media and CDR/ DVD R LightScribe version 1.2.
7. Advanced media lab for DVD and BD testing and development

Technology adaptations efforts

1. Installation of variable speed drive air compressors to eliminate loading and unloading losses.
2. Installation of the heat exchangers in the power plant to extract energy from the lubricating oil used in the engine.
3. Saving in lighting energy by synchronizing with daily cycles.
4. Installing variable frequency drive (VFD) systems for power savings in air handling units

In the aggregate, the company made an investment of approx. Rs.3.02 million. As a result of extensive steps taken by the company to reduce the consumption of energy is Rs 47.3 mn annually.

New technologies were adopted in following areas during year 2006-07:

1. Production of following new 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. Development of an entirely new design of co-sputtering machine in collaboration with IIT, Delhi.

3. Production of following new products: DVD+RW 8x DVD-RW 1x-2x Mini RW CDR/DVD R LightScribe version 1.2 Special Printable Process
4. DVD and Blu-ray disc test set up
5. Format verification set up
6. Playability test set up
7. Print evaluation set up
8. Crystallization and dye studies.

Technology adaptations efforts

1. Installation of 90 drives of variable frequency in clean room air handling units in various plants resulting in the saving of 947 KW in terms of energy and Rs. 37.9 million in terms of cost by incurring an expenditure of Rs. 12.4 million for this purpose.
2. Reduction in the canteen power consumption which resulted in saving of 10 KW in terms of energy and Rs. 0.4 million in terms of cost, without incurring any specific expenditure.
3. Energy saving of 57 KW and Rs. 2.3 million in terms of cost in the lube oil separators by investing Rs. 0.4 million.

5.4.5 SWOT analysis

On the basis of the study carried out in Moser Baer, SWOT analysis has been done in which the strengths, weaknesses, opportunities and threats for this company has been identified. This SWOT analysis has been summarized in table 5.6.

Table 5.8 SWOT analysis: Moserbaer India Limited

Strengths	Weaknesses
• Lower capital investment compared to industry standards and high process efficiencies enables global cost leadership. • Integrated and Flexible manufacturing facility that enables adapting to changing market dynamics. • Cutting edge R&D infrastructure that enables development of superior technology products and faster commercialization of the same to emerge "first to market". • Involvement of suppliers in long term strategic sourcing aspects for critical material supply. • 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. • Large investments of funds, manpower and resources in the short term. • Internal control and information systems for handling large number of product variants across segments.

• Presence in multiple technologies within each business segment. • Excellent project management and large-scale production skills that enable faster technology commercialization. • Emergence as technology developer from a technology innovator.	
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. • The company has emerged as the second largest player for DVDR/RW formats in the world - a segment which is to grow tremendously. • Well positioned to dominate domestic 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. The initiative should also increase Moser's brand equity in Indian market.	• **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. • **Protective govt policies in international markets:** 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. • **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.

5.4.6 Current status of technology adoption

The most important objectives of Moserbaer for adoption and adaptation of new technologies increased competitiveness, reduced product cost, and increased market share. The company's prime focus is on being highly competitive in the market by reducing the product cost resulting in increased market share.

Moserbaer's location is not within in the cluster of similar industries. Its plants are located considerably near a metro city, thus it does not face any problems regarding infrastructural facilities or labor scarcity.

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

Moserbaer strongly participates in inter-company groups and networks consisting of other original equipment manufacturers (OEMs). Moserbaer works on Japanese concepts and does not believe in rework and remanufacturing. Quality standards and procedures are followed with a true spirit. 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. It avails assistance from IITs, universities or other reputed research institutes. It has great capabilities to reengineer its manufacturing process.

In order to meet market requirements, the Moserbaer have always been developing and adopting new technologies to keep its products leaders in international and domestic markets. It adopts new technology immediately on its availability. It considers to a large extent the alternate processes that can be developed in house for making new technology cost effective. The company adopts new technology covering all processes and operations. It carries out extensive analyses based on past trends before going in for new technologies. It also carries out economic viability studies for adopting new technologies and analyses quantitative and qualitative effects in details. Before adopting a new technology, it considers consequential changes in related products and processes and plans alternatives for these in detail. For adopting new technologies, the company involves its manpower in it from the very beginning.

Its officials also visit foreign countries to get new ideas to develop new technologies in-house.

The role of government in technology adoption in the company is not encouraging. It does not provide any incentives or other benefits for adopting new technology. However its pollution control related regulations do not affect company operations to a large extent.

Globalization plays a crucial role in Moserbaer's endeavor to update its technology to the latest available. Opportunities created due to globalization in form of vast international markets lead Moserbaer to produce world class products using most advanced technologies. The threats posed by globalization in form of big competitors in domestic market require it to maintain its technology at up-to-date level so as to deliver very high product quality. Availability of better technologies due to globalization has significantly influenced Moserbaer in new technology adoption.

Top management support has always been a key factor responsible for new technology adoption. Their top management is always ready for taking short term risks for long term improvements and allocates sufficient funds for new technology adoption.

Manufacturing strategy of the company specifically addresses the continuous technology upgradation requirements. The benefits of new technology are communicated to all the concerned personnel, which helps in its easy adoption. The objectives of new technology adoption are well defined and this assists in its successful adoption. In-house engineers enthusiastically participate in technology upgradations, thereby play positive role in new technology adoption. Attitude of the employees is aligned towards the objectives of new technology adoption and this significantly helps in its easy adoption. Training programmes are conducted for all classes of users ranging from top management to shop floor controllers.

Moserbaer has very amiable relationships with the suppliers of new technology, thus facilitating its successful adoption. Suppliers of new technology are selected using thorough and extensive evaluation process and this selection process affects new technology adoption. New technology is also developed in-house in company's own R&D division.

Moserbaer has well laid new technology adoption polices. These policies are used extensively and thoroughly, reviewed and updated periodically. These policies also track technology adoption costs and further help in technological capability building of the company.

For Moserbaer, critical barriers to technology adoption are (i) likely obsolescence of technology (ii) cost of training and education, (iii) cost of new technology.

The company has faced a few problems when a new technology is brought in contact with old technology. These problems include (i) difficulty in operating and maintaining new technology and (ii) lack of co-operation and understanding, and (iii) lack of knowledge about the new technology to a considerable extent.

Overall the company is fully satisfied with the results achieved after the adoption of new technologies.

5.4.7 Current status of technology adaptation

Since most of the technologies used by Moserbaer are developed in-house by the company's R&D division, the need of technology adaptation is very low. Only minor adjustments need to be carried out to the existing system and the new technologies to make these compatible with each other. The company has to redesign their production system to some extent to achieve satisfactory ergonomic and safety layout of machines, standardization of equipment, effective use and presentation of controls, and instrumentation and smooth flow of materials.

For adapting new technologies, Moserbaer redesigns its organizational structure to some extent. People are shifted to some extent within the company and a few suitable persons are recruited from outside. Training is imparted to all concerned personnel to a considerable extent. New methods are devised for performance and efficiency measurement. It also puts in some efforts to make new technology acceptable to employees.

Top management always provides full support for technology adaptation initiatives. It is always ready for taking short-term risks in order to derive long-term benefits to be derived from technology adaptation. Top management provides sufficient funds for adaptation of new technologies.

At Moserbaer, the overall education level of employees is quite high and this facilitates the process of technology adaptation. Further, this company employs a lot of skilled workers, and thus makes the process of technology adaptation much easier. Technocratization of the company is very high and it is one of the key factors responsible for successful adaptation of new technology. Its in-house R&D of Moserbaer is very strong and is very helpful in smooth adaptation of new technology. Staff of the company is usually willing to accept changes.

The company has well defined technology adaptation policies, which are used thoroughly and extensively. These policies include the training requirements of all concerned employees and include procedures and practices for smooth adaptation of new technology. These policies are reviewed and updated regularly, and helpful in building technological capabilities of Moserbaer.

At Moserbaer, the effectiveness of technology adaptation has increased to some extent by empowerment, extensive training, open communication within the organization, job security, and rewards and recognitions.

Overall, the company is fully satisfied with the results achieved after adaptations of new technologies.

5.4.8 Technological capabilities

Moserbaer is well aware of the technologies most important to its business. Technology plays an important part in its business strategy. The company is well equipped to assess technology opportunities and threats. Moserbaer has special technological strengths which it exploits to a large extent. The company knows well which technologies to outsource and which to develop in-house.

The management of Moserbaer has a well developed technology vision and is fully skilled at formulating a technology strategy to meet business goals. It is fully capable to select the technology needed for its business and is well aware of the best sources of technology.

Moserbaer is very effective at acquiring technology from external sources and maintain good links with important suppliers of technology. It has well organized technological activities in engineering and R&D areas. The company has well developed processes for carrying out technology projects and a good system for assessing these. It carries out post project reviews as well. The company is able to learn from one technology project to another.

Govt. policies have no motivational role to play in Moserbaer's investment in new technology. Moserbaers uses external organizations (consultancy firms) to assist in technology assessment, and use outside bodies to help it in developing new technology or in implementing its technology strategy. It works with universities / government R&D organizations for its key technology projects.

Moserbaer has developed acquiring capability to a considerable extent. It can easily justify and specify clearly the technologies to be bought; identify the most suitable mechanism(s) for buying technology; negotiate effective terms for the transaction of the technology, identify funding sources and obtain funds at competitive rates for expansion and growth, effectively access necessary material inputs for production and is efficiently undertaking project planning and execution.

The company has also developed modifying capability to a considerable extent so it can duplicate acquired machinery and equipment, parts requiring replacement; adapt installed technology and system components for better efficiency; carry out minor, incremental improvements for superior quality outputs; implement human resources development programs for all activities, introduce advanced management techniques for effective performance and prepare production system expansion programmes and implement these properly.

The company has accumulated transforming capabilities to a large extent so it is effectively utilizing available plant and equipment, planning and controlling production operations, carrying out troubleshooting and good predictive, preventive and emergency (breakdown) maintenance; and quickly changing over to diverse products.

The company has built up vending capabilities to a large extent by selling outputs for optimum use of resources and production capacity; monitoring external situation and evaluating performance; identifying new markets and promoting sales of new products in new markets; and providing after-sales services to enhance perceived customer satisfaction.

The company has also developed innovating capabilities to a large extent. It can reverse engineer acquired technology; carry out product and process innovations; and introduce core competence leveraging innovations.

The present status of overall technological capabilities of Moserbaer India Limited have been shown in figure 5.4.

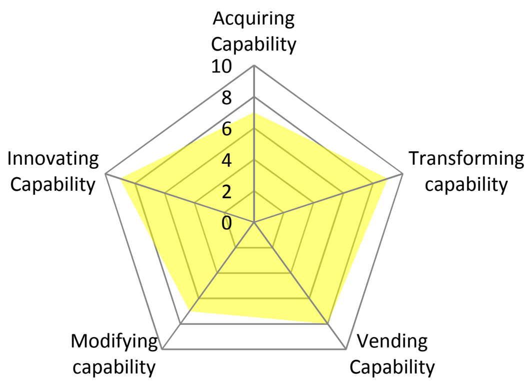

Figure 5.6 Technological capabilities of Moserbaer India Limited

So the technological capability of Moserbaer is categorized as Creative under classification of technological capabilities in chapter IV. The company has a fully-developed set of technological capabilities and is able to help extend the international technology frontier further. In many areas it takes a creative and pro-active approach in exploiting technology for competitive advantage.

5.4.9 SAP analysis

Based on the above mentioned practices in the process of technology adoption and adaptation and technological capabilities, the situation-actor-process (SAP) analysis of MIL has been done.

Situation

- 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.
- Technology collaborations 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.
- High cost of new technology, high cost of training and likely obsolescence are the technology are the biggest barriers to new technology adoption.
- The company faces the problems like difficulty in operating and maintaining new technology, lack of co-operation and understanding and lack of knowledge about the new technology, when existing and new technologies are brought into contact.
- Moserbaer does not face any major barrier in adaptation of new technology.
- The company is fully satisfied with the technology adoption and adaptation practices.
- The company has ability to plan and manage technical changes effectively and efficiently

- The company is well aware of technology issues and the need to acquire technologies.
- The company has the capability to seek out and identify technologies to solve particular problems.
- The company has ability to assess and select cost effective technology solutions.

Actors

- Chairman, Board of Directors as the key decision maker.
- Managing Director, to manage day to day affairs.
- Managers and Supervisors of the company as a dedicated lot.
- Skilled, trained and flexible work force, eminent academia scientists and entire value chain as key knowledge provider.
- Reputed OEMs as demanding customers.

Process

Technology Adoption 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.
- Involving manpower in process of technology adoption.
- 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.

Technology Adaptation Aspects

- The top management provides full support for technology adaptation activities.

- 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.
- Depending upon the requirements, the company redesigns its organizational structure. The people are shifted within or are recruited from outside.
- Extensive training is imparted to employees.
- Skilled workers easily adapt to new technologies.
- The company has well defined technology adaptation polices which are thoroughly used and regularly updated.
- The effectiveness of adaptation is increased to a considerable extent by empowerment, extensive training, job security and rewards and recognition.
- In-house R&D greatly facilitates the process of technology adaptations.

Technological Capability Aspects

- The company develops technology strategy, which includes framework with priorities and action plan.
- The company is acquiring, developing and absorbing all necessary technologies.
- The company is successfully implementing the new technologies in various areas.
- The company is learning and accumulating experience in order to continuously improve technological capabilities.
- The company is building core capabilities in some critical area and exploiting these to the maximum extent.
- The company is forming and exploiting linkages with networks of technology suppliers and others involved in technology.

5.4.10 Learning issues

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

The company is achieving its three objectives namely to increase competitiveness, to reduced product cost, and to increase its Market Share, to a large extent by adoption and adaptation of new technologies for all of the operations and processes of the company in a timely and planned manner.

Company is investing significant amount in new machinery and equipment, and in R&D efforts, besides getting strong technical support Maruzen Corporation, Japan and Moser Baer Sumiswald, Switzerland. Its officials visit foreign countries to get new ideas to develop new technologies in-house.

Technology adoption

It has always adopted new technologies immediately on its availability to match the market requirements and considered alternate processes that can be developed in-house for making new technology cost effective. The company also conducts extensive analyses based on the past trends, and studies economic viability for its quantitative and qualitative effects, before going in for new technology. It also considers consequential changes in its diverse products and processes and plans alternatives in detail.

Though there is no government encouragement to adopt new technologies directly or through its industry policies, yet its regulations related to environment, pollution control and safety have required the company to adopt new technologies from time-to-time. Opportunities or threats caused due to globalization necessitate adoption of new technologies in the company, and easy availability of new technology – due to globalization – is also a very significant factor for its new technology adoption.

Technology adaptation

It develops most technologies in-house in anticipation of market requirements, so it has little need for technology adaptation for its organizational structure or production system. It also adopts new technology from alliance partners to reduce the lead-time to new product introduction. In-house R&D of the company is very strong and is very helpful in smooth adaptation of new technology. Its employees are usually willing to accept changes. High effectiveness of technology adaptation is there because of empowerment, extensive training, open communication, job security, and rewards and recognition of employees. Strong linkages with academic and research institutions help in technology adaptation as well as capability building.

Technological capabilities

The company is well aware of the most important technologies for its business, and includes technology in its business strategy. The company has a technology vision and it is capable of identifying technology opportunities and threats, and its priorities

It has effective acquiring capabilities from external sources and maintains good links with important external suppliers of technology. It also works with universities / Government R&D organizations for its key technology projects.

The company has built up vending capabilities to a large extent by selling outputs for optimum use of resources and production capacity; monitoring external situation and evaluating performance; identifying new markets and promoting sales of new products in new markets and providing after-sales services to enhance perceived customer satisfaction.

It takes a creative and pro-active approach in exploiting technology to its fullest for getting competitive advantage.

5.4.11 Actions suggested

- Improve its internal control and information systems for handling a large number of product variants across segments.
- Develop capability for consolidating technology infrastructure in its diverse segments and sectors.

5.4.12 Performance expected

- Retain and increase its domestic market share and increase its exports.
- Develop as a turn-key supplier for new high tech consumer products.

5.5 PUNJAB TRACTORS LIMITED (PTL)

Punjab Tractors Limited 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 and in result witnessed a tough job for maintaining its position in the farm equipment sector.

5.5.1 Company's competitive strategy

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 tractor manufacturing company in world bought a controlling 43% stake in Punjab Tractors Ltd. that will reportedly increase M&M's share in the domestic tractor market from just over 30% to nearly 40%. The 43% stake in PTL includes the 29% owned by Actis and 14.2% by the Delhi-based Burman family. In July 2007, Mahindra upped its share in PTL to 64.6%.

PTL has regained the number one brand position in Punjab after a gap of six years in 2008 after the takeover of its management by the new team as all 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 and Mahindra Ltd.

The snapshot of the milestones are delineated and presented in the Table 5.12.

Table 5.9 Milestones of Punjab Tractors Limited

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. and Sumitomo Corpn. 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) and 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 are 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 favour of CDC Financial Services (Mauritius) Ltd. With this, total holding of CDC and its associates in PTL stands at 28.48%.
2004	• 7th and 8th tractor models - Swaraj 939 (41 HP) and Swarj 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 upto 30 HP range.
2007	• Mahindra and 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. and then raised to 64.6%

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 franchises, restructuring dealerships and introduction of new products. Additionally, the company has now the advantage to synergize with Mahindra and Mahindra (M&M) Farm Equipment Sector (the market leader in the tractor industry) in the areas of product development, manufacturing technology 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 variations 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 over the 2003- 08 has been discussed and presented in figure 5.7.

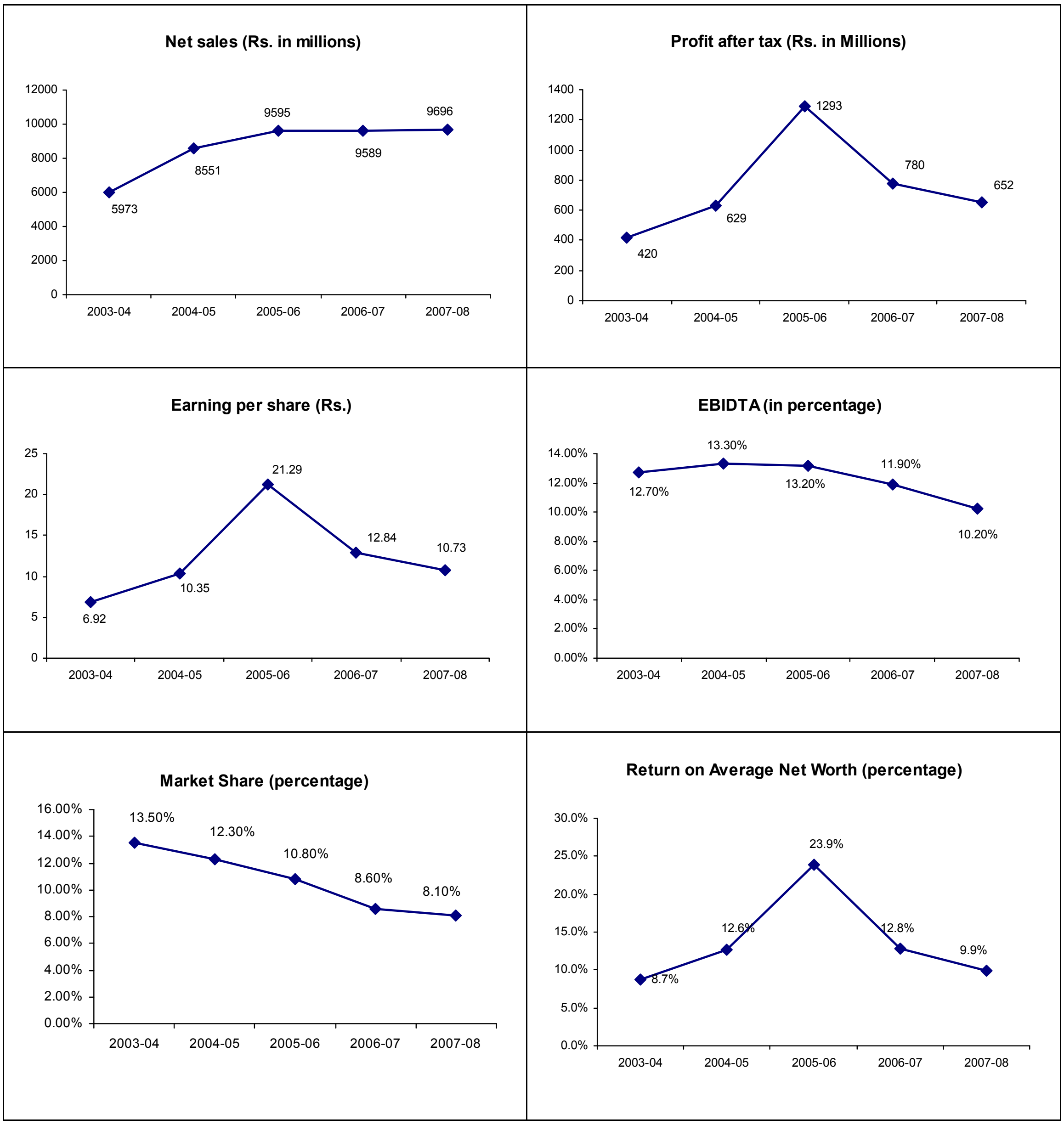

Figure 5.7 Performance indicators of Punjab Tractors Limited

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 regained to Rs. 9696 mn in year 2007-08.

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 were at Rs. 10.35, against Rs. 6.92 in 2003-04, a rise of 50%. Earnings per share for 2005-06 jumped 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 slashed to Rs. 12.84 and which 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 tumbling 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 Current practices

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 manufacturing technologies, 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 achieved the target of selling 5 lakh 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 refrained the company's profit margins and position in the market during the later five years.

The company has launched a number of models in the different segments from time to time. The company has high-level modification capability through its internal research. The products have been continually modified for their technological and operational aspects. The company is building and utilizing its technological capabilities in the critical strategic decision-making process. However, due to cost reduction exercises, value-engineering efforts, better buying practices and technological synergy with Mahindra and Mahindra Ltd. the company is trying to retain and regain its market share in the recent times.

5.5.4 New technology – adoption and adaptation

The company has not imported any technology during the past 5 years, however through local R and 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 past 5 years from 0.8 to 1.21%. R&D expenses added up to Rs. 8.9 crores, 0.9% of total product revenue for 2007-08 as against Rs. 8.5 crores (0.9%) during 2006-07. Major research and development activities and new technology adoptions by PTL in the previous years have been delineated below:

New technologies were adopted in following areas during year 2004-05:

- Engines of all tractor models upgraded to meet Bharat Stage III emission norms and cleared for regular introduction after extensive lab and field evaluation.
- Top of the line tractor model Swaraj-978 FE, equipped with global features, commercially introduced in overseas market in 2WD and 4WD versions.
- Development and introduction of suitable variants of existing tractor models to meet region/application specific requirements of discerning customers.
- On going programme of continuous product improvement for performance, reliability and cost effectiveness continued with vigor.

Technology adaptations efforts

- Reduction of idle time between loadings of charges in Seal Quench Furnaces.
- Optimization of Gas Carburizing Furnaces in terms of process and loading.
- Reorientation of air lines to plug air leakages.
- Modifications in cleaning cycle of PTC Tank/Seal Quench Furnace Heaters for efficient transfer of heat.
- Redefining of running cycle of all Air Conditioners in the plant.

New technologies were adopted in following areas during year 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.

Technology adaptations efforts

- Optimized air fuel ratio in diesel fired burners.
- Improved efficiency of intercoolers and reduced temperature of air intake for better compressor efficiency.
- Improved power factor for getting rebate from State Electricity Board.
- Optimized use of heat treatment furnaces.

New technologies were adopted in following areas during year 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.

Technology adaptations efforts

- Improvement in power factor to 0.97.
- Modification in running cycle of Shot Blasting Machine.
- Switching off of idle transformer in 66KV yard.
- Installation of transparent fiber sheets at suitable locations to increase daylight in Shop Floors.
- Heater for use during winter derated from 2000 Watts to 1500 Watts.
- Introduction of regular de-scaling of PTC Heaters for better efficiency.
- Total annual expected savings - Rs.8.0 lakh.

New technologies were adopted in following areas during year 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 and developed by in-house R&D was commercially launched.
- Swaraj 3 tonne battery forklift, designed and developed by in-house R&D was commercially launched.
- On-going product improvement projects for performance, reliability and value addition continued with vigor.

Technology adaptations efforts

- Automatic power factor installed to bring power factor to 0.99.

- Cold washing system introduced in washing machines using improved chemicals.
- Installation of variable frequency drive.
- Reconditioning of sealed quench furnaces (3 nos.) to reduce heat loss.
- Coating on four furnaces to reduce heat loss.
- Total annual expected savings - Rs.12.0 lakh.

5.5.5 SWOT 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 5.13 shows the SWOT analysis at PTL.

Table 5.10 SWOT analysis: Punjab Tractors Limited

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 threshers. • 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 • Government decision to disinvest its share to M and M.	• 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 • Competition with Chinese cheap alternatives

5.5.6 Current status of technology adoption

The most important objectives of PTL for adoption and adaptation of new technologies and building technological capabilities are increased competitiveness, improved productivity, and increased market share. The company's prime focus is on being highly competitive in the market by improved productivity resulting in increased market share.

PTL is not located in the cluster of similar industries. It is located considerably near to a metro city, so it does not face any problems regarding infrastructural facilities or labor scarcity.

It exports a few of its products to international markets, thus the advanced technology is the sustenance of PTL. The products to be exported have to meet international requirements which are very stringent with regard to reliability, safety and pollution.

PTL strongly participates in inter-company groups and networks consisting of other Original Equipment Manufacturers (OEMs) and vendors. PTL works on Japanese concepts (Juran) but still needs to do some rework and remanufacturing. Quality standards and procedures are followed morally. It seeks advice to a considerable extent from its customers in order to improve its products and thus the voice of customers has got a good place in this company.

PTL avails assistance to a considerable extent from government's R&D organizations. It possesses sufficient capabilities to reengineer its manufacturing process.

In order to meet market requirement, the PTL have normally been developing and adopting new technologies to keep its products at par with those of competitors in international and domestic markets. At present, the company is using intermediate technology for its products. The company adopts new technology when it gets popular. It considers to some extent the alternate processes that can be developed in house for making new technology cost effective. The company adopts new technology in most of the important processes and operations. PTL does extensive analyses based on the trends of the past years before going in for new technology. It conducts some economic viability study for adopting new technology and analyzes quantitative effects in details. Before adopting new technology, PTL considers, in general, consequential changes in related products and processes. The company passes on some information to its manpower regarding adoption of new technologies.

At PTL, the officials often visit foreign locations to get new ideas to develop new technologies in house.

At PTL the role of government in technology adoption is encouraging. Government extended its support and other benefits for adopting new technology. Further, government provided excise exemption to this company during initial years. Government regulations (pollution related) force the company operations to a large extent.

Globalization plays a crucial role in PTL's endeavor to upkeep its technology to the latest available. Opportunities created due to globalization in form of vast markets motivated PTL to produce world class product using available technologies. Similarly, the threats caused by globalization in form of big competitors in domestic market force PTL to keep its technology and product quality abreast with competition. Availability of better technology due to globalization did not affected PTL's new technology adoptions.

At PTL the top management support has always been a factor responsible for new technology adoptions. The top management is normally ready for taking short term risks for long term improvements and allocates sufficient funds for new technology adoption.

The manufacturing strategies of PTL specifically include the continuous technology upgradation requirements. The benefits of new technology are communicated to all the concerned personnel, which helps in its easy adoption. The objectives of new technology adoption are well defined and it assists in its successful adoption.

In-house engineers of PTL participate in technology upgradations, thereby play positive role in new technology adoption.

In most of the cases, the new technology is developed in-house by company's own R&D division.

At PTL, the attitude of employees is aligned towards the objectives of new technology adoption and it significantly helps in its easy adoption. Formal education and training programmes are developed for all classes of users ranging from top management to shop floor controllers.

PTL has some new technology adoption polices.

Among the critical barriers to technology adoption in PTL are (i) cost of training and education, (ii) cost of new technology development and subsequent adoption and (iii) skill deficiency for new technology.

The PTL faces a few problems when a new technology is brought in contact with old technology. These problems include (i) difficulty in operating and maintaining new technology and (ii) lack of co-operation and understanding to a considerable extent. The fear of layoffs is also faced to some extent.

Overall the PTL is satisfied to a considerable extent with the results achieved after the adoption of new technologies.

5.5.7 Current status of technology adaptation

Since most of the technologies used by PTL are developed in house by the company's R&D division, the need of technology adaptation is very low. Only minor adjustments are needed to be done to the existing system and the new technology to make these compatible with each other. The company has to redesign their production system to some extent to achieve satisfactory ergonomic and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation.

For adapting new technology, PTL does not need to redesign its organizational structure. People are shifted to some extent within the company. Some suitable persons are also recruited from outside. Training is imparted to all concerned personnel to a large extent. Some new methods are devised for performance and efficiency measurement. Some efforts are put in to make new technology acceptable to employees.

The government has been somewhat supportive in technology adaptation efforts of PTL. The top management provides support for technology adaptation initiatives. It is usually ready for short term risks in order to get long term benefits to be derived from technology adaptation. The top management provides sufficient funds for adaptation of new technology.

At PTL, the overall education level of employees is high, which facilitates the process of technology adaptations. Further this company has a lot of skilled workers which makes the process of technology adaptation much easier. The technocratization of PTL is very high and it is one of the key factors responsible for successful adaptation of new technology.

In-house R&D of PTL is strong and helpful in smooth adaptation of new technology. People at PTL are usually willing to accept changes.

PTL does not have well defined technology adaptation policies.

At PTL, the effectiveness of technology adaptation is increased to a considerable extent by empowerment, extensive training, open communication within the organization, job security, rewards and recognitions.

Organizational rigidities within the company has been identified as a significant barrier to technology adaptation at PTL.

Overall, the PTL is satisfied to a considerable extent with the results achieved after the adaptations of new technology.

5.5.8 Technological capabilities

PTL is well aware of the technologies most important to its business.

Technology plays an important part is PTL's business strategy.

The company is well equipped to assess technology opportunities can also assess the technological threats to some extent. PTL has special technological strengths which it is exploiting to a large extent. The company well knows which technology to outsource and which to develop in house.

The management of PTL is fully skilled at formulating a technology strategy to meet business goals. PTL knows its main technology priorities and has a well developed technology vision.

PTL is full capability to select the technology needed for its business and is well aware of the best sources of technology.

PTL is effectively acquiring technology from internal sources and maintain good links with important external suppliers of technology. Further the technological activities like engineering and R&D are well organized within PTL. 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. The company is able to learn from one technology project to another.

Govt. policies have little motivational role to play in PTL's investment in new technology. PTL use external organization (consultancy forms) to assist in technology assessment. PTL does not use outside bodies to help it in developing new technology or to implement its technology strategy. Further, now it does not work anymore with universities / government R&D organizations for its key technology projects.

PTL possess acquiring capability to a some extent and can justify and specify the technologies needed based on detailed engineering studies and translate basic process parameters into layout, plant and equipment; identify funding sources and obtain funds at competitive rates for expansion and growth, effectively access necessary material inputs for production and is efficiently undertaking project planning and execution.

The company possesses modifying capability to a considerable extent so it can duplicate acquired machinery and equipment parts requiring replacement; adapt installed technology and system components for better efficiency; carry out minor, incremental improvements for superior quality outputs; implement human resources development programs for all activities, introduce advanced management techniques for effective performance and prepare production system expansion programmes and implement it properly.

The company possesses transforming capabilities to a considerable extent so it is effectively utilizing available plant and equipment, planning and controlling production operations, carrying out troubleshooting, predictive, preventive and emergency (breakdown) maintenance; quickly changing over to new models; and using computerized information and control systems to provide information support and networking for production operations.

The company has built up vending capabilities to a very large extent, thereby selling outputs for optimum use of resources and production capacity; monitoring external situation and evaluating performance; identifying new markets and promoting sales of new products in new markets and providing after-sales services to enhance perceived customer satisfaction.

The company also possesses innovating capabilities to a considerable extent. It can carry out product and process innovations; and introduce core competence leveraging innovations.

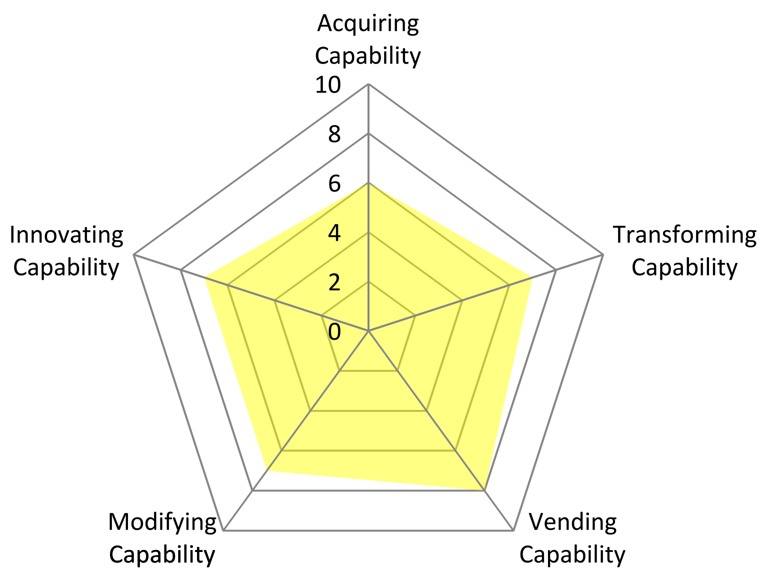

Figure 5.8 Technological capabilities of Punjab Tractors Limited

So the technological capability of PTL is categorized as Strategic as discussed in chapter IV. The company has strong in-house capabilities and takes a strategic approach to technology. In some areas, the firm is behind the international technology frontier but has much important strength upon which to build.

5.5.9 SAP analysis

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.

Situation

- PTL has developed its own technology, without any collaboration.
- Getting exemption of the excise duty.
- Employment for a large number of people.
- Supporting a large number of engineering ancillary units.
- Localized vendors ensuring easy supply of components at reduced costs.
- Import Substitution.
- Advanced R&D facilities for tractors and harvester combines.
- 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.
- Cost of training and education, cost of new technology development and subsequent adoption and skill deficiency for new technology are the biggest barriers to new technology adoption.
- The company faces the problems like difficulty in operating and maintaining new technology and lack of co-operation and understanding and lack of knowledge about the new technology and fear of lay offs is also faced to some extent, when old and new technologies are brought into contact.
- The company does not face any major barrier in adaptation of new technology.
- The company is fully satisfied with the technology adoption and adaptation practices.
- The company has ability to plan and manage technical changes effectively and efficiently
- The company is well aware of technology issues and the need to acquire technologies.
- The company has the capability to seek out and identify technologies to solve particular problems.
- The company has ability to assess and select cost effective technology solutions.

Actors

- Punjab State Industrial Development Corporation (PSIDC).
- Representative of Government (PSIDC) as Chairman of PTL.
- Management of Mahindra and Mahindra Ltd.
- Vendors and dealers
- Skilled, trained and flexible work force,.
- All the customers through feedback and suggestions.

Process

Technology Adoption 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.
- Developing individual capabilities to acquire and diffuse the scientific and technical knowledge.
- Saving costs through technology and efficient working including intelligent engineering concept.
- Involving manpower in process of technology adoption.
- Extensively using in-house capabilities for making new technology cost-effective
- Officials visit foreign countries to get new ideas to develop new technology in-house.

Technology Adaptation Aspects

- The top management provides full support for technology adaptation activities.
- 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.
- The people are shifted within or are recruited from outside.
- Extensive training is imparted to employees.
- Skilled workers easily adapt to new technologies.
- The company has well defined technology adaptation polices which are thoroughly used and regularly updated.
- The effectiveness of adaptation is increased to a considerable extent by empowerment, extensive training, job security and rewards and recognition.
- In-house R&D greatly facilitates the process of technology adaptations.

Technological Capability Aspects:

- The company develops a technology strategy, which includes a framework with priorities and an action plan.
- The company is developing and absorbing all necessary technologies.
- The company is successfully implementing the new technologies in various areas.
- The company is learning and accumulating experience in order to continuously improve technological capabilities.
- The company is building core capabilities in some critical area and exploiting these to the maximum extent.
- The company is forming and exploiting linkages with networks of technology suppliers and others involved in technology.

5.5.10 Learning issues

Based on the detailed study and analysis of the initiatives taken by PTL to increase competitiveness, productivity and market share, the following issues have emerged for learning. The company is achieving its three objectives to a large extent by adoption and adaptation of new technologies for most of the important operations and processes of the company in a timely and phased manner.

Technology adoption

The company has relied on government research institute technology and design and over the years developed technologies on its own supported by its own R&D, but did not import any new technology. Its approach to technology adoption has primarily been reactive and to those processes and activities that are in dire need of it. Management support has helped its R&D efforts to develop new technologies. Therefore, it requires lesser adaptation efforts for in-house developed technology that is customized to its specific requirements. In house R&D has helped the company to indigenously develop and implement automation so as to reduce cycle time. Government has always been supportive to its business and technology adoption as the company was a public sector company since inception till a few years ago.

Technology adaptation

The company develops most of the technologies in-house in anticipation of market requirements, so there is little need for technology adaptation. The in-house R&D of the company is very helpful in smooth adaptation of new technology, wherever required. Its employees are usually willing to accept changes. The government has been somewhat supportive in its technology adaptation efforts.

Technological capabilities

PTL has developed very strong vending and modifying capabilities, but could not develop transforming and innovating capabilities to the fullest extent. The company has strong in-house capabilities and takes a strategic approach to develop technological capabilities, except in a few areas, where it is behind the international technology frontier.

5.5.11 Actions suggested

- Upgrade existing technologies sooner.
- Diversify its product portfolio
- Change its work culture of a public sector unit to that of a private enterprise.
- Develop capabilities for acquisition, modification, transformation, and innovation of new technology.

5.5.12 Performance expected

- Regain, retain and increase its domestic market share.
- Develop as a north Indian hub for quality tractor and mechanized machinery for industrial use.

5.6 CONCLUDING REMARKS

Critical analysis of case studies conducted in four manufacturing organizations has shown little variation in priority of objectives for technology adoption and adaptation. Examination of practical difficulties and constraints faced by these companies due to dynamic market environments like intense competition, pressure to reduce product cost while improving its quality, and shorter product life-cycles require strong technological capabilities for survival. It has also been observed that various organizations are using different approaches for building technological capabilities through flexible management of technology adoption and adaptation. Learning issues for case studies have been synthesized in the next chapter.

CHAPTER VI

DEVELOPMENT OF AN IMPLEMENTATION PLAN FOR BUILDING TECHNOLOGICAL CAPABILITY

6.1 INTRODUCTION

This chapter presents inferences drawn from empirical study carried out in manufacturing industries 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 strategies for technology adoption and adaptation 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, a qualitative model has been developed for building technological capability showing preferred strategies under various conditions of optimism, pessimism, and realism.

6.2 SYNTHESIS OF LEARNING ISSUES

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

- Companies adopt and adapt new technologies mainly with these objectives:
    - to increase competitiveness,
    - to reduce costs
    - to increase product quality, and
    - to increase productivity
- Companies can build their technological capabilities by managing their technology adoption and adaptation in a flexible manner.

6.2.1 Issues concerning technology adoption

Specific issues that have emerged out of study of processes and practices at firm-level regarding technology adoption are:

- New technology is adopted to match the future requirement.
- New technology is adopted when its performance is proved.
- New technology is adopted for most important processes.
- Alternate process that can be developed in house for making new technology cost effective are considered before adopting new technology
- Analysis based on past trends is carried out before going for new technology.
- Economic viability of new technology and analyze its quantitative and qualitative effects is studied.
- Consequential changes in related products and processes are considered
- Manpower is involved from beginning of adopting new technology.
- Encouragement for adopting new technologies through government and its agencies is desired.
- Adoption of new cleaner technologies is required to meet government regulations related to environment or pollution control.
- Some incentives for cleaner technologies in industry policies are desired.
- Adoption of new technology is necessitated by opportunities and threats caused by the globalization
- Easy availability of new technology due to globalization contributes for its adoption.
- Top management support is an indispensable prerequisite for new technology adoption.
- Formal manufacturing strategies address new technology adoption needs.
- Well defined objectives of new technology helps in its adoption.
- Understanding of new technology benefits is desired.
- Well defined technology adoption policies is desired.
- Inclusion of training of the employees at all levels in technology adoption policies is desired.

- Regular updation of technology adoption policies is desired.
- Human factor plays a crucial role in new technology adoption.
- In-house engineers actively participate in new technology adoption.
- Positive attitude of employees towards objectives of new technology adoption smoothens the process.
- For adopting new technology, formally qualified personnel are desired.

6.2.2 Issues concerning technology adaptation

- Redesigning the production systems to achieve ergonomics and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and to ensure the smooth flow of materials is needed.
- Redesigning the organization structure, internal shifting of people and recruiting suitable persons from outside for successful adaptation of new technologies is needed
- Imparting training to personnel and designing new methods of performance and efficiency measurement are also needed
- Making efforts for employees' acceptability of new technology are needed
- Implementing some changes in product design and features, plans and procedures during technology adaptations.
- Staffing and production flexibilities considerably affect the adaptability of new technology.
- The effectiveness of the technology adaptation process can be considerably enhanced by empowerment; extensive training; open communication within the company; job security to employees; and rewards and recognitions.
- Government's role in adaptation of new technology is very limited.
- The top management support is vital for technology adaptation
- Readiness of top management for taking short term risks for long term benefits is desired.
- Availability of skilled workers helps in easy adaptation of new technology.
- Technocratization facilitates technology adaptation.
- Employees' willingness to accept changes is beneficial for technology adaptation.

- In-house R&D is very important for new technology adaptation.
- Technology adaptation policies are lacking.

6.2.3 Issues concerning technological capabilities

- Awareness about role of technology in companies' competitiveness is a must.
- Monitoring external technology events and trends is desired.
- Defining individual technological strengths and building up a unique advantage in each specific area are desired
- Formulation of a technology strategy is a key part of the overall business strategy.
- Collection of information on range of available technological options, quick choice among competing solutions and identification of most appropriate sources to fulfill the needs are required.
- Deployment of resources to exploit the selected technological option is carried out by two options: (a) development of in-house technology facilitated by R&D, and (b) acquisition of new technology through joint venture / technology licensing.
- Implementation of acquired technology via its adaptation or reconfiguration.
- Review of technology projects and processes within the firm to learn from success or failures.
- Maintenance and nurturing links with different kinds of external organizations for getting many technology related services is desired.
- Carrying out continuous improvements in all technological related activities and components is desired
- Effective utilization of available technologies for transformation of raw material into finished goods.
- Utilization of relevant technologies in distribution, service and sale of products.
- Development of process development technologies by reverse engineering the acquired technology with product / process innovations.

6.3 METHODOLOGY FOR MODELING

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, 1994). A brief description of the model is given below.

The modeling began with listing of options as a solution to flexible management of new technology adoption and adaptation for building technological capabilities. The list was converted into a conceptual design. OFM/OPM (Warfield 1979, 1982, 1990) was largely used as a basis for this purpose. Lastly, the alternative options profiles developed were ranked using AHP (Saaty, 1980) and FST (Zadeh 1965).

6.3.1 Options field / Options profile methodology

In order to adapt the method of idea writing to design as Warfield (1979) – using the team idea management – introduced a methodology for the conceptual design of systems which results into a portrayal on one page of the products of a conceptual design. 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.

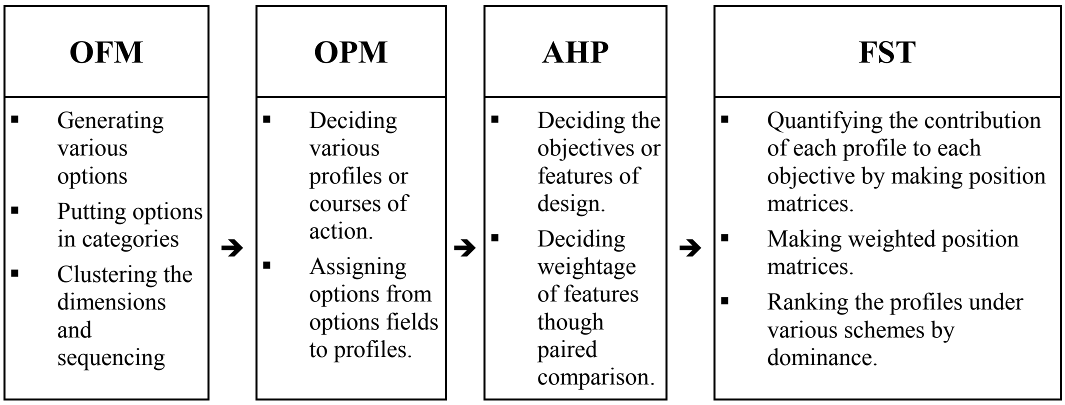

Figure 6.1 Qualitative modeling

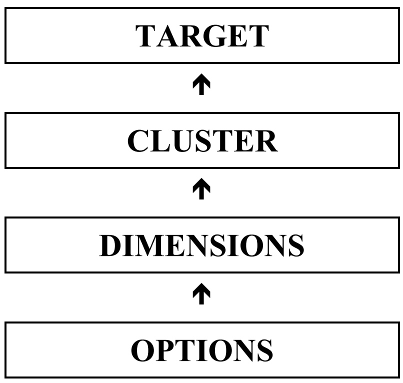

Figure 6.2 Four level structure quad

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 neither be 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 the purpose of 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.

c) *Naming the categories*: Following the placing of options into categories, options are displayed as sets, arrayed vertically in anticipation of developing a name for each category that will be placed at the head of the appropriate column options.

d) *Identifying 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.

e) *Discovering Clusters of dependent dimensions*: Once the group has settled on the dimensions of the target, a second structuring occurs. Now it is the set of dimensions that 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.

f) *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."

g) *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.

h) *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 atleast 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 a n by n reciprocal judgment matrix. In this 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 of elements. 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.

Values 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 seriousness of 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 as given by Saaty and Kearns (1985) are:

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 blurred 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, systems 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 represent 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 d_{ij} 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 d_{ij} element. If the K^{th} column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the K^{th} row is summed, the number of times the K^{th} option is being dominated by all other options is determined. More favorable outcomes 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. 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 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. Consider increased competitiveness as first objective of new technology adoption and adaptation.
2. Consider improved product quality as second objective.
3. Consider improved productivity as third objective.
4. Management of technology adoption and adaptation for building technological capabilities flexibly.
5. Adopt new technology to match the future requirement.
6. Adopt new technology when its performance is proved.
7. Adopt new technology for most of the important processes.
8. Consider those alternate processes that can be developed in house for making new technology cost effective.
9. Conduct analysis of the past trends before going for new technology.
10. Study economic viability of new technology
11. Analyze quantitative and qualitative effects of new technology.
12. Consider consequential changes in related products and processes.
13. Involve the manpower from the very beginning of new technology adoption.
14. Encouragement for adoption of new technologies by government.
15. Adopt new and cleaner technologies because of environment or pollution related regulations of government
16. Avail incentives for new technology adoption through industry policies.
17. Consider opportunities or threats of the globalization for new technology adoption.
18. Consider availability of new technology due to globalization.
19. Consider availability of top management's support for new technology adoption.
20. Develop formal manufacturing strategies to include new technology adoption needs.
21. Understand the benefits of new technology.

22. Define clearly the objectives of new technology.
23. Formulate and use the technology adoption policies.
24. Regularly update technology adoption policies.
25. Identify role of Human factor in new technology adoption.
26. Involve manpower in the process of new technology adoption
27. Make participation of in-house engineers in new technology adoption.
28. Align the attitude of employees towards objectives of new technology adoption.
29. Provide formal education and training programmes for employees at all levels through technology adoption polices.
30. Redesign the production systems to achieve ergonomics and safety layout of machines,
31. Standardize the equipment
32. Plan effective use and presentation of controls and instrumentation
33. Ensure smooth flow of materials.
34. Redesign the organization structure for adaptation
35. Shift people internally for adaptation
36. Recruit suitable persons from outside for adaptation.
37. Impart extensive training to concerned personnel.
38. Design new methods of performance and efficiency measurement.
39. Put efforts to make new technology acceptable to employees.
40. Implement changes in manufacturing during technology adaptations.
41. Alter product design and features during technology adaptations
42. Change plans and procedures for technology adaptations.
43. Empowerment of employees
44. Facilitate open communication within the company
45. Provide job security to employees
46. Implement mechanism for rewards and recognitions for enhancing the effectiveness of technology adaptation.
47. Consider role of government in adaptation of new technology.
48. Take top management’s support for technology adaptation

49. Arrange sufficient funds for technology adaptation.
50. Take short term risks in order to have long term pay offs.
51. Consider availability of skilled workers.
52. Technocratization in the company.
53. Make employees willing to accept changes.
54. Develop in-house R&D.
55. Formulate well the technology adaptation policies.
56. Include procedures and practices in technology adaptation policies
57. Remain aware of role of technology in company's competitiveness.
58. Scan or monitor external technology events and trends.
59. Define individual technological strengths and build up a unique advantage in specific area.
60. Formulate a technology strategy as a key part of the overall business strategy.
61. Gather information on range of technological options available.
62. Choose quickly among competing solutions
63. Identify the most appropriate source which fits with its needs.
64. Deploy resources to exploit the selected technological option either by creating technology through in-house R&D or by acquiring it through a joint venture / technology licensing or otherwise.
65. Implement the acquired technology which may involve various stages like its adaptation or reconfiguration.
66. Reflect upon and review technology projects and processes within the firm in order to learn from success or failures.
67. Maintain links with different kinds of external organizations which may provide them technology related services.
68. Carry out continuous improvements in all technological related activities and components.
69. Effectively utilize available technologies for transformation.
70. Utilize the relevant technologies in distributing, selling or servicing its outputs.
71. Utilize process development technologies.

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) Building technological capabilities through acquiring, transforming, vending, modifying and innovating capabilities.

b) Setting short term and long term goals

c) Planning, analysis and validation in detailed

d) Setting objectives of new technology adoption and adaptation.

e) Getting top Management support

f) Allocating funds for various technological activities.

g) Formulating technology adoption and adaptation policies

h) Retaining trained and skilled workforce

i) Creating special teams and departments

j) Involving all concerned

k) Developing human resource development through formal education and trainings.

l) Making sustained and regular efforts

m) Reviewing technology upgradation plans

n) Formulating manufacturing strategy

o) Focusing on the entire problem

p) Developing economic and viable strategies

q) Implementing system / structural changes

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

These dimensions were classified into broader categories called clusters. The principles of clustering have already been explained. Clusters 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:

i. Development of appropriate strategies

a. Focusing on the entire problem
b. Developing economic and viable strategies
c. Implementing system / structural changes

ii. Continuous improvement

a. Making sustained and regular efforts
b. Reviewing technology upgradation plans
c. Formulating manufacturing strategy

iii. Involvement and development of human resource

a. Creating special teams and departments
b. Involving all concerned
c. Developing human resource development through formal education and trainings.

iv. Professionally managed companies

a. Setting objectives of new technology adoption and adaptation.
b. Getting top Management support
c. Allocating funds for various technological activities.
d. Formulating technology adoption and adaptation policies
e. Retaining trained and skilled workforce

v. Strategic planning

a. Building technological capabilities through acquiring, transforming, vending, modifying and innovating capabilities.
b. Setting short term and long term goals
c. Planning, analysis and validation in detailed

6.4.5 Options profile methodology

Various profiles or courses of action identified for flexible management of new technology for developing its technological capabilities are:

I. **Hard technology adoption approach**: A firm can adopt new technologies directly for its manufacturing applications, such as, CNCs, robots, FMS, AS/RS etc. These may include:

- Adoption of new technologies to match the future requirements.
- Adoption of new technologies for most of the important processes.
- Sustained and regular efforts
- Creation of facilities
- Manufacturing strategy and technology adoption policies.

II **Soft technology adoption approach**: A firm can also adopt new technologies for manufacturing support activities like design softwares or other infrastructural technologies, such as, ICT, ERP, MRP, JIT, GT etc.

III **Technology adaptation approach**: A firm may go in for localizing adopted technology (hard or soft or both) to make those appropriate for use in existing system. These may include:

- Standardization of the equipment
- Effective use and presentation of controls and instrumentations
- Measures to ensure smooth flow of material
- New methods for productivity measurements
- Joint R&D efforts

IV **System adaptation approach**: In this approach, a firm makes changes in its existing system to make it appropriate for new technology like redesign of production system or organizational structure, changes in practices and procedures etc. Activities in this approach may include:

- Re-design of existing production systems.
- Redesign of existing organizational structure
- Internal shifting of people
- Fresh recruitment of suitable manpower.

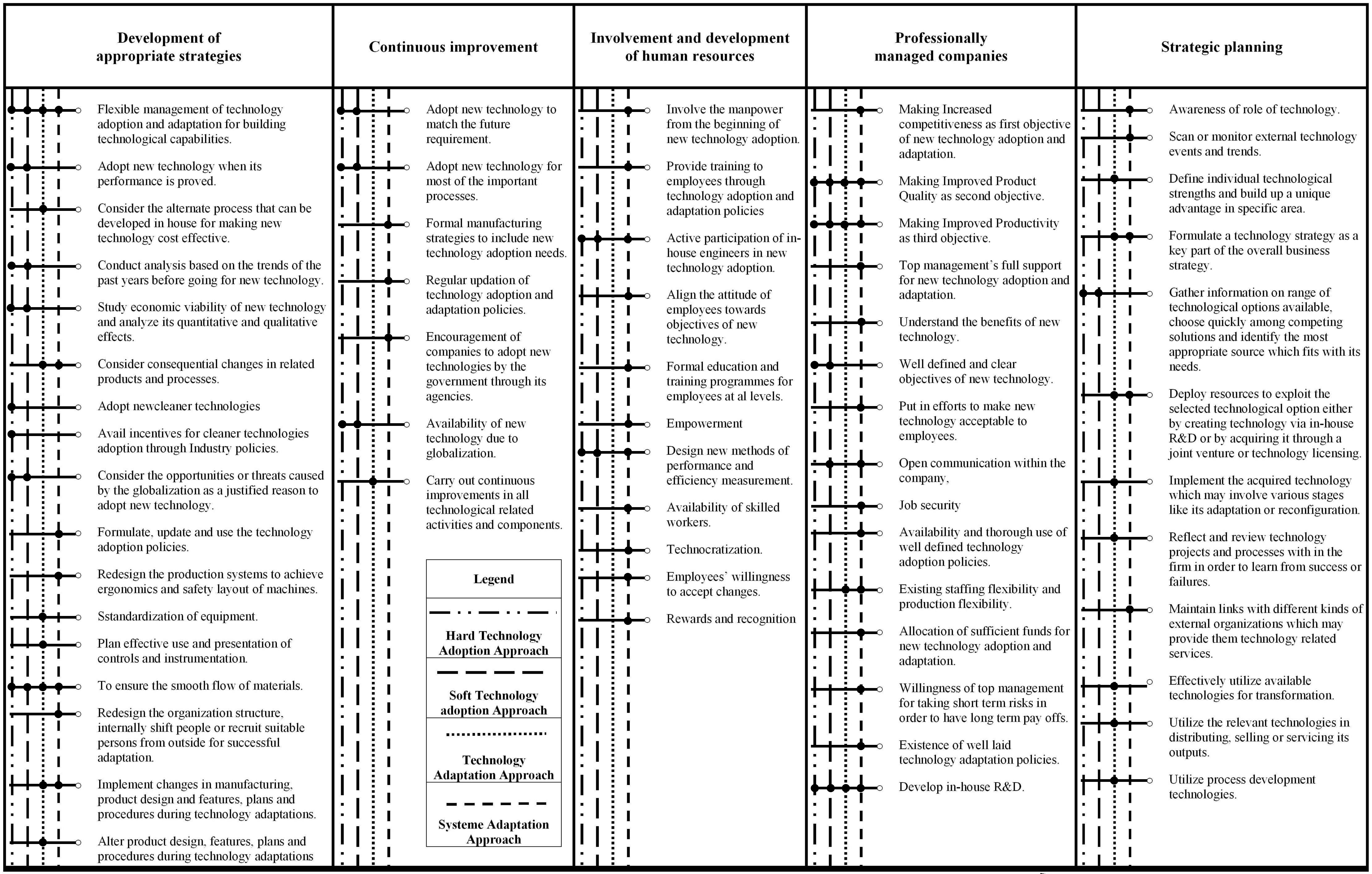

Figure 6.3 Options Profile Methodology

- Formal Evaluation Systems
- Effective co-ordination system
- Empowerment, job security, rewards and recognitions
- Open communication in organization
- Creation of special teams, departments
- Involvement of all concerned
- Human resource development

After identifying various profiles or approaches, the next task was 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 Fig. 6.3 (OPM).

6.4.6 Analytic hierarchy process modeling

Technological capabilities have been categorized in five following categories (Paul, 2004).

- Acquiring Capabilities
- Transforming Capabilities
- Modifying Capabilities
- Vending Capabilities
- Innovating Capabilities

Each of these capabilities has to be individually developed by the companies for building overall technological capabilities. Among these five categories of technological capabilities, the acquiring capabilities and vending capabilities can be developed by almost all organizations as these are not very critical. A company may not need capability of a higher level to acquire technology as a lot of commercial / general technologies are available, which do not require some special selection criterion. Any company can outsource its vending capabilities easily without significantly affecting its technological capabilities. So, the critical capabilities that make the difference in overall technological capabilities of a company include other three types of capabilities i.e. transforming capability, modifying capability and innovating capability. The further analysis is done considering these three capabilities.

Paired comparison method of analytical hierarchy process was applied to find out the weightage of each objective. Each objective was compared with each other, independently by three respondents. These were: technology manager of Swaraj Enterprises; General Manager, R&D, Maruti Udyog Limited and the researcher himself. The respondents compared the objectives on a qualitative scale of the difference between the importance 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 – F. These matrices also show the calculation of Eigen vector and the weights of objectives. The weightages 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 participants is given in Table 6.2.

Table 6.1 Weights of various technological capabilities

Participant ⇨ Objective ⇩	Researcher	Technology Manager	R&D Manager
Transforming Capabilities	0.156	0.105	0.114
Modifying Capabilities	0.185	0.258	0.405
Innovating Capabilities	0.659	0.637	0.481

The role of innovating capabilities has been found to be foremost among other categories followed by modifying capabilities and then transforming capabilities for building overall technological capabilities of organizations. Relative weightages scored by transforming capability are quite less than other two types of capabilities i.e. modifying capability and innovating capabilities. This could be attributed to the fact that for building firm-level technological capabilities, the innovating capabilities and modifying capabilities have bigger roles to play. Most of the companies can adopt and use technology for transforming their raw materials into finished goods, but only a few can modify these technologies to suit their requirements, and further a very few of these companies can learn from these technologies and then innovate new technologies on their own. So the highest level of technological capability is achieved when a firm develops innovating capability.

6.4.7 Fuzzy set theory

After determining the weights of the objectives, the next step was to make position matrices. In these matrices, the qualitative value of contribution of each profile or approach to each of the three capabilities was to be decided. This exercise was done by each of the three participants independently. The position matrices along with the weights determined earlier are given in Appendix – G.

From the position matrices, weighted position matrices were determined. This has also been done individually for the matrix from each respondent. The weight of the objective as determined earlier was multiplied by value of each position of the position matrix and weighted values were obtained. Appendix – H shows the weighted position matrices.

From these weighted position matrices, optimistic, average and pessimistic weighted position matrices were made using Fuzzy Set Theory. For optimistic matrix, the highest value of each position was selected, for pessimistic the lowest values and for average matrix, the average values were selected. Tables 6.3 to 6.5 show these values.

Table 6.2 Optimistic weighted position matrix

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1406	0.0781	0.1093	0.0798
Modifying Capabilities	0.2027	0.1291	0.2838	0.2027
Innovating Capabilities	0.3293	0.4459	0.5928	0.5733

Table 6.3 Pessimistic weighted position matrix

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.0733	0.0570	0.0524	0.0524
Modifying Capabilities	0.0926	0.0556	0.1296	0.1296
Innovating Capabilities	0.1442	0.1976	0.3364	0.3364

Table 6.4 Average weighted position matrix

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.0979	0.0695	0.0805	0.0701
Modifying Capabilities	0.1415	0.1021	0.1981	0.1710
Innovating Capabilities	0.2215	0.2946	0.4584	0.4569

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. Preferred strategies for building transforming capabilities, modifying capabilities and innovating capabilities under various degrees of optimism have been compiled in Table 6.5.

Table 6.5 Preferred strategies for building various capabilities

Optimism ⇨ Objectives ⇩	100% Optimistic	80% Optimistic	Average	20% Optimistic	100% Pessimistic
Transforming Capabilities	I-III-IV-II	I-III-IV-II	I-III-IV-II	I-III-II-IV	I-II-III-IV
Modifying Capabilities	III-IV-I-II	III-IV-I-II	III-IV-I-II	III-IV-I-II	I-II-III-IV
Innovating Capabilities	III-IV-II-I	III-IV-II-I	III-IV-II-I	III-IV-II-I	III-IV-II-I

I: Hard technology adoption approach ***II: Soft technology adoption approach***

III: Technology adaptation approach ***IV: System adaptation approach***

The following conclusions have been drawn from the Hadley's matrix of cautious optimism as detailed in Table 6.5.

- Transforming capabilities of an organization represent its proficiency in effectively utilizing available plant and equipment; planning and controlling production operations; carrying out troubleshooting and maintenance; and quickly changing over to different products in shortest time. For building transforming capabilities, the hard technology adoption approaches contributes highest under all conditions of optimism. After adopting hard technologies, transforming capabilities can be further enhanced by adaptation of technology, whereby it is made suitable to localized conditions. Under conditions of higher optimism, the system adaptation and soft technologies also contribute, though a little, in building transforming capabilities.
- Duplicating acquired machinery; adapting installed technology for better efficiency and carrying out minor incremental improvements for superior quality

outputs are the key functions under modifying capabilities. Adaptation of technology primarily influences the development of modifying capabilities under almost all of the optimism conditions (except 100% pessimistic), closely followed by system adaptation approach. Further, hard technology adoption and soft technology adoption approaches moderately influence the development of modifying capabilities. However, in pessimistic conditions, due to resistance to change, hard technology adoption approach takes first place and system adaptation takes the last place for developing modifying capabilities.

- Product and process innovations alongwith easily reverse engineering acquired technology are the key aspects of the innovating capabilities. Technology adaptation approach has emerged as the primary and most important aspect in developing innovating capabilities under all conditions of optimism. The innovating capabilities can further be developed by system adaptation approach and then by soft technology adoption approach. However, hard technology adoption approach contributes only minimally for developing innovating capabilities.

Following this, dominance matrices were prepared considering overall technological capabilities. In these matrices, the dominance of each course of action over the others has been tabulated. In Table 6.6 to Table 6.9, cell value denotes, number of times, the domination of a profile written on the top, over a profile written on the left. The column sum depicts the number by which the profile dominates all other profiles.

Table 6.6 Dominance matrix - optimistic

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	1
Soft technology adoption approach	2	--	3	3
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	0	3	--
Column Sum	4	1	8	4
Rank	**2**	***4***	***1***	**2**

Table 6.7 Dominance matrix - pessimistic

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	2	2
Technology Adaptation approach	1	1	--	0
System Adaptation approach	1	1	0	--
Column Sum	4	3	4	4
Rank	**1**	**4**	**1**	**1**

Table 6.8 Dominance matrix - average

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	3	3
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	0	3	--
Column Sum	4	1	8	5
Rank	**3**	**4**	**1**	**2**

The similar dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled in Appendix – K. The results of these dominance matrices have been summarized in Table 6.9

Table 6.9 Hadley's matrix of cautious optimism

Optimism ⇨ Profiles ⇩	**100% Optimistic**	**80% Optimistic**	**60% Optimistic**	**40% Optimistic**	**20% Optimistic**	**100% Pessimistic**	**Average**
Hard technology adoption approach	II	III	II	II	II	I	III
Soft technology adoption approach	IV	IV	IV	IV	IV	IV	IV
Technology Adaptation approach	I	I	I	I	I	I	I
System Adaptation approach	II	II	II	II	II	I	II

The Hadley's matrix of cautious optimism in Table 6.9 indicate that technology adaptation approach has affirmed as the most preferred strategy whereas soft technology adoption approach has occupied the last (fourth) position for building technological capabilities under all degrees of optimism. System adaptation approach and hard technology adoption approach have occupied almost equal rank under various degrees of optimism.

The dominance matrix for average values or a high degree of optimism (80%) seems to be the most realistic strategy. In these matrices, technology adaptation approach has emerged as the most preferred strategy; system adaptation approach has got the second rank, whereas hard technology adoption approach and soft technology adoption approach have come into sight as the preferred strategies ranked as number three and four respectively.

6.5 DISCUSSION

Results of qualitative modeling have clearly depicted that more or less, all the approaches like optimistic, average, pessimistic and Hadley's cautious optimism have brought out the following as the preferred strategies for building technological capabilities in Indian manufacturing industry.

i) Technology adaptation approach

ii) System adaptation approach

iii) Hard technology adoption approach

Currently India is passing through a transition phase, in which globalization and liberalization have made significant impact on Indian manufacturing industry. The competition has already reached unprecedented levels. In these circumstances, a pessimistic approach in technology management is not expected to succeed. On the other hand, a pure optimistic approach may also not yield the desired results because of the government rules and regulations, (which are at present, a bit in favor of the employees), the attitude of the employees in general, and the kind of work culture existing in the country. In such a scenario, a cautious optimism approach with quite a high degree of optimism can be successful.

Technology adaptation approach is the most preferred strategy in all the dominance matrices. System adaptation approach and hard technology adoption approach occupy the second and third position respectively at 80% optimism. To sum up, the following three strategies in order of their importance have emerged to be workable ones for building technological capabilities.

1. Technology adaptation approach
2. System adaptation approach
3. Hard technology adoption approach

Technology adaptation approach

The qualitative modeling has clearly indicated that for building technological capabilities, the most preferred strategy is technology adaptation approach. Further, technology adaptation approach has also emerged as the most preferred strategy in developing modifying capabilities and innovating capabilities individually. At the same time for developing transforming capabilities, the technology adaptation approach has been ranked as second most preferred strategy.

Technology is important, but almost all companies can have access to these technologies and rather quickly. The competitive edge a company can keep on a long term basis is not just by buying a new machine but by learning to use that equipment in a certain application. When a new technology is adapted, deployment is more likely to succeed, in some cases with less system adaptation, but when the new technology cannot be adapted and the company faces large system adaptations that it cannot successfully make, the new technology is not successfully deployed. Technology adaptation processes include standardization of equipment, effective use and presentation of controls and instrumentation, and to ensure the smooth flow of materials etc.

Technology adaptation also cover joint R&D efforts for considering the alternate process that can be developed in house for making new technology cost effective, conducting analysis based on the trends of the past years before going for new technology, studying economic viability of new technology and analyze its quantitative and qualitative effects and considering consequential changes in related products and processes.

There is sufficient support in the literature for the mutual adaptation of the system and the technology. Mutual adaptation can be effectively described as a tradeoff. An optimal level of adaptation for technology or system cannot be determined independently. When exogenous constraints are placed upon organizations for adaptation of technologies, results in terms of deployment are less than the optimal. Taking the extreme examples, if the new technology is rigid and technology adaptation is necessary but not possible, then only system can be adapted, within the organization itself. A potential exists for the organization to need to adapt itself to a potentially harmful extent. In such a case, an organization would most likely reject the product, either before or after adoption. At the other extreme, if system adaptation is needed but the organization cannot or will not adapt to it, the entire dependence for adaptation is on the technology. This creates the potential that the organization will want to adapt the technology to an extent that violates the basic tenets of the technology's underlying models. Most real cases of new technology adoption (with the exception of custom-built applications) appear to be more aligned with the first example, where the organization must adapt itself. Thus, an additional factor appears to affect the success of the deployment of new technologies - the degree of system and technological adaptation required to use the new technology effectively versus the degree of system and technological adaptation that is possible.

Sometimes, adaptations may be infeasible because they are either technically impossible or too expensive to implement with current technologies.

Technology adaptation usually occurs after adoption and is initiated by the adopter. In the long run, the learning process and the adaptation of technologies ultimately depend on the communication and exchange of information between partners during technology transfer. The supplier of the technology has control over production modes and design decisions, which make their product, i.e. the technology, more or less easily adapted. A goal of the technology supplier can be to select a production process that provides the best match between the degree of technology adaptation required and the degree possible. Thus, maintaining good relations with supplier facilitates the process of technological adaptation.

The technological adaptations significantly depend upon the human factor in terms of their education, technical expertise, attitude, involvement, and training etc. It has been found that transition required for a successful technology adaptation is achieved when (a) each partner actually carries out these complementary tasks for which he is responsible according to contract, (specific competence); (b) partners share a common technical language that enables effective communication (generic competence); and (c) participants recognize and respect their partners' distinctive work styles.

When technology adaptation takes place under extremely demanding conditions, it offers an excellent opportunity to upgrade actual or potential competencies available in the receptor company. The successful adaptation of a technology that is to be efficiently used in a new context depends on the establishment of an on the spot communication process regarding specific theoretical and practical knowledge. It is usually assumed that the ability to develop, build and properly operate production equipment is a capacity that goes naturally together with technology. However, the key to successful adaptation does not lie in the drawings, the equipment and their description manuals or in the formality of contractual guarantee clauses. It is to be found in something not formalized or formalizable that resides in the minds of the cooperating parties: the generic aspects of their competences that allow them to communicate in order to carry out specific tasks jointly and efficiently. So the mechanism design is very important to explicitly create conditions for successful implicit adaptation.

System adaptation approach

The system adaptation approach has emerged as the second most preferred strategy for developing overall technological capabilities. Various strategies for system adaptation include redesign of organizational structure, products, its features, production systems, and manufacturing processes to achieve ergonomics and safety layout of machines. Employees' empowerment, extensive training, open communication within the company, job security, and rewards and recognition make the process of system adaptation smooth.

In a highly interconnected world in which the pace of change is accelerating, organizations are forced to achieve high performance levels in the short-run, and a capacity to adapt to change in order to survive and succeed in the long-run.

After an inherently complex technology is adopted by an organization, the implementation process requires somewhat more than just communication of knowledge. The technology must be adapted to the organizational context and the relevant organizational processes within broad work culture of the organization, and routines may need to be adapted to the technology. The implementation of advanced technologies can be seen as a process of mutual adaptation of the technology and the system. That is, the system (the user, the organization and its norms, procedures, etc.) must be adjusted to accommodate the technology, and the technology must be reinvented or adapted to the environment. Inherently complex technologies, particularly those that affect the organization's core processes, require significant organizational change.

The system must be modified to use the technology effectively. Custom-made technologies lie at one extreme of the technology spectrum, while generalized technologies lie at the other. By definition, a custom-made technology should fit all of a client's specifications. On the one hand, a company would, therefore, not be required to modify a custom-made technology, while customers of commercial / generalized technologies usually would require both technology and system adaptations on the other.

The need for system adaptation could be related to the structure and assumptions that underlie a new technology, or to response to customers' needs to adapt the technology in the face of constraints that make it difficult for them to do so. In such cases, the system may be adapted to compensate for the adaptations in the technology that would have been preferred by the customer. The best strategy, from a resources standpoint, is to minimize the degree of system and technological adaptation beyond optimal levels.

A major problem firms facing worldwide is the adoption of new technology and the adaptation of the firm to technological change. Therefore, firms need to formulate strategies that enable them to maximize their opportunities for benefitting from these new technologies. This approach means that more attention must be paid to the problems of system adaptation as part of the problem of managing technology within the firm. The problems of adaptation must be looked at, and a set of necessary conditions be developed for management to make a transition to a new technology in a way that would help the company in achieving its goals. These problems are difficult ones and require an interdisciplinary approach.

In a globalized economy, firms may pursue two approaches for survival and success. These involve developing a capacity to innovate continually either in products that create greater value for customers or in processes which are more resource-efficient and/or environment-friendly. The latter is related to an ability to adapt faster to a continually changing business landscape. Both the ability to innovate and the ability to adapt depend on the quality of network flows for materials, information, and human communication. The potential for environmental changes in the adopting organization may be limited by internal factors (e.g., the organization's own norms and policies or formal structure) or by external factors (e.g., laws of governmental bodies or industry-wide competitive forces). The system adaptation also significantly depends upon the human factor in terms of their education, technical expertise, attitude, flexibility, involvement and training etc. Extensive training and formal education as an element of a human resource development enables all organizational processes to operate more efficiently in a self-reinforcing manner. Thus, raising the level of training – personal, organizational or inter-organizational – not only enhances the exploration, testing, and evaluation of new ideas but also improves coordination for performing ongoing tasks.

Changing mindsets of human resources is a difficult task. Preparing employees in advance to new technologies helps them in their acceptance of new technology.

Preparation and development of human resources not only can bring the required change in their attitudes, but also can improve their skill levels and involvement in the endeavors of the company. This introduces human flexibility in the process of adaptation. Multi-functional task forces or teams should be used when a company plans to adapt a new technology in order to avoid waste of time, effort and other resources later. Teamwork seems to be one of the preferred approaches in flexibly managing technology adoption and adaptation. Further, human resource development strategies should be aimed to inculcate some essential capabilities in the human resources, such as capabilities in:

a. improvising and diversifying their skills
b. making decisions and solving problems
c. communicating effectively
d. understanding the process as a whole
e. adapting to new situations
f. continuous learning

It is now generally accepted that abandoning some traditional managerial concepts in order to develop a flexible workforce is necessary. One such concept is the complete separation between planning/controlling and executing tasks. These tasks are not any more the old, simple, and repetitive ones based on "scientific management" principles. The new reality demands flexibility, which requires decentralized decision making, improved skills to solve non-repetitive problems, planning and self-control skills of those who perform the job or, in other words, managerial skills beside technical excellence. The idea of teamwork is basic to create conditions for workers where they can develop improved skills and managerial ability. These conditions can be created largely by the way the workers are managed by supportive supervision rather than directive; continuous learning, not only on technical aspects but also on managerial aspects; and largely by rewarding considering group performance and skill levels of the worker rather than considering individual performance. Therefore, a flexible workforce is increasingly becoming important for a firm which intends to achieve high levels of competitiveness.

Hard technology adoption approach

The hard technology adoption approach has emerged as the most preferred strategy in developing transforming capabilities of an organization. However for developing complete set of technological capabilities, it ranks as the third most preferred strategy.

Because of ever-increasing competition, the companies cannot increase the prices of the products in direct proportion to increase in input costs. They can become competitive and survive in the market only by reducing cost. This can be achieved by lowering the operational costs and avoiding waste of any kind. New technologies, while ensuring higher output of products with lower expenditure on resources, economies of scale and scope are the answer to the present crisis in manufacturing sector. The industry must adopt new technologies to match with the future requirements. New technology should be adopted for most of the important processes. Firms must formulate manufacturing strategies that have the components to assess new technology adoption needs.

However, because of the reducing market share of each company due to increasing number of competitors in the market, the companies do not have the kind of funds to replace technology in all areas in a single go like in reengineering. Rather, the companies have to be very selective and should choose the area of technology improvement very carefully. That area should be selected which involves maximum gains with minimum expenditure. This will facilitate easy adoption, adaptation and assimilation of new technology. In addition, the areas should be chosen in such a way that the rule of whole-to-part and part-to-whole is satisfied, that is, the areas of technology adoption and adaptation, though independent, at one point of time, should ultimately get integrated to achieve transformation of the whole company after a specified amount of time. Indian companies should, therefore, bring in new technology in a phased manner making the process as a process of continuous improvement.

6.6 APPROACHES TO TECHNOLOGICAL CAPABILITY BUILDING – A CONCEPTUAL FRAMEWORK

Based on literature review, survey results, case studies and qualitative modeling, a conceptual framework representing linkages between technology adoption and adaptation with technological capability building has been developed. In this framework, various approaches to technological capabilities building have been presented in figures 6.4 and 6.5.

Specific elements constituting various approaches have been discussed at length in this thesis. This framework suggests preferred flexible approaches to build technological capabilities at a high degree of optimism (using Hadley matrix of cautious optimism) for different types of technological capabilities, namely, transforming capabilities, modifying capabilities, and innovating capabilities, besides for overall technological capabilities.

Figure 6.4 represents the cyclic process of developing technological capabilities through flexible management of technology adoption and adaptation. Technological capability building process starts from technology adoption. Technology adaptation is the next stage in this cyclic process. Facilitated by technology adoption and adaptation, a company develops its technological capabilities, and this completes a cycle. By virtue of acquired technological capabilities, the company then proceeds for adoption of next level of technology, after the adaptation of which, technological capabilities of the company are further developed and the cycle continues.

In figure 6.4, factors affecting technology adoption and adaptation are also shown, with significant factors in bold letters. Types of technological capabilities are also shown in this figure with critical types in bold letters.

Further in figure 6.5, interplay of preferred flexible approaches for various types of technological capabilities is shown. This framework suggests four possible approaches for developing technological capabilities, namely (i) hard technology adoption approach, (ii) soft technology adoption approach, (iii) technology adaptation approach and (iv) system adaptation approach, represented by circular platform in figure 6.5. Vertical arrows show relative priorities of these approaches for developing various types of technological capabilities at a high degree of optimism (80%). Length of an arrow represents priority of an approach. Technological capabilities that can be developed using one or more of these approaches are shown at the top in varying intensity of green color, where darkness of color represents high importance.

6.7 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 flexible management of new technology adoption and adaptation in manufacturing industry for building technological capabilities. Although the findings– based on the survey, case studies and qualitative modeling of medium and large scale firms using new technology – are in the context of manufacturing firms of northern India, yet their 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.

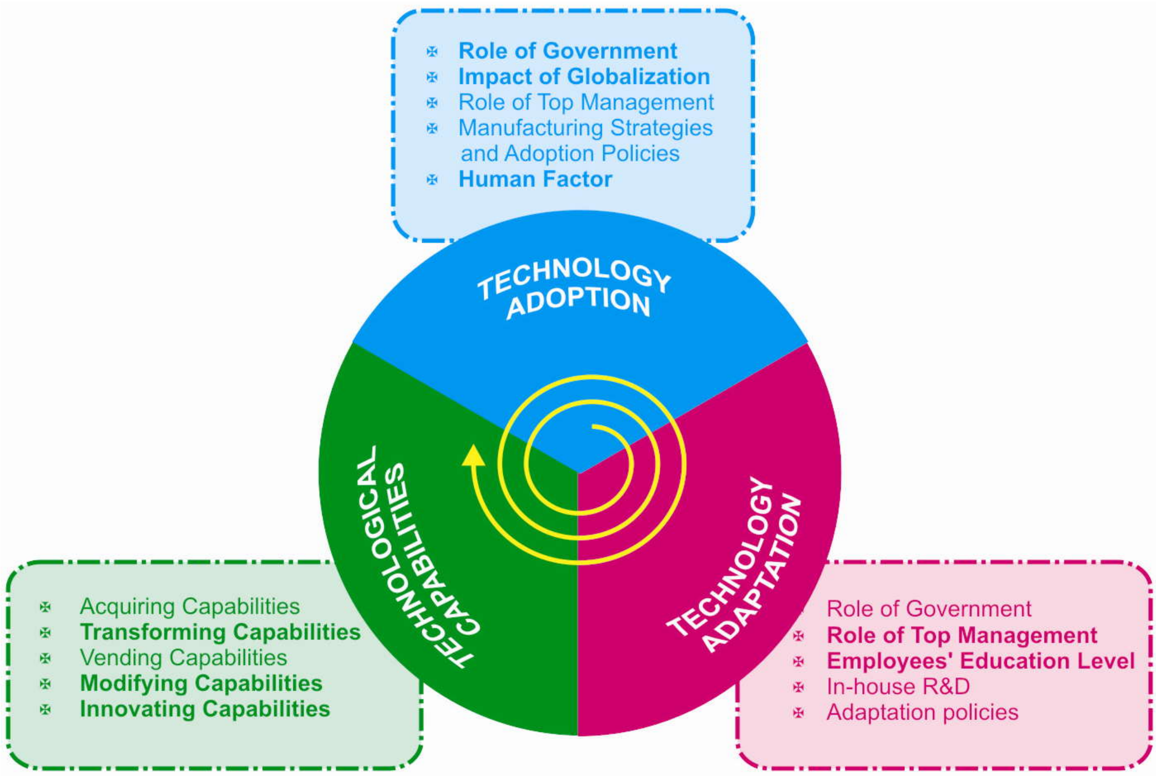

Figure 6.3 Cyclic process of developing technological capabilities

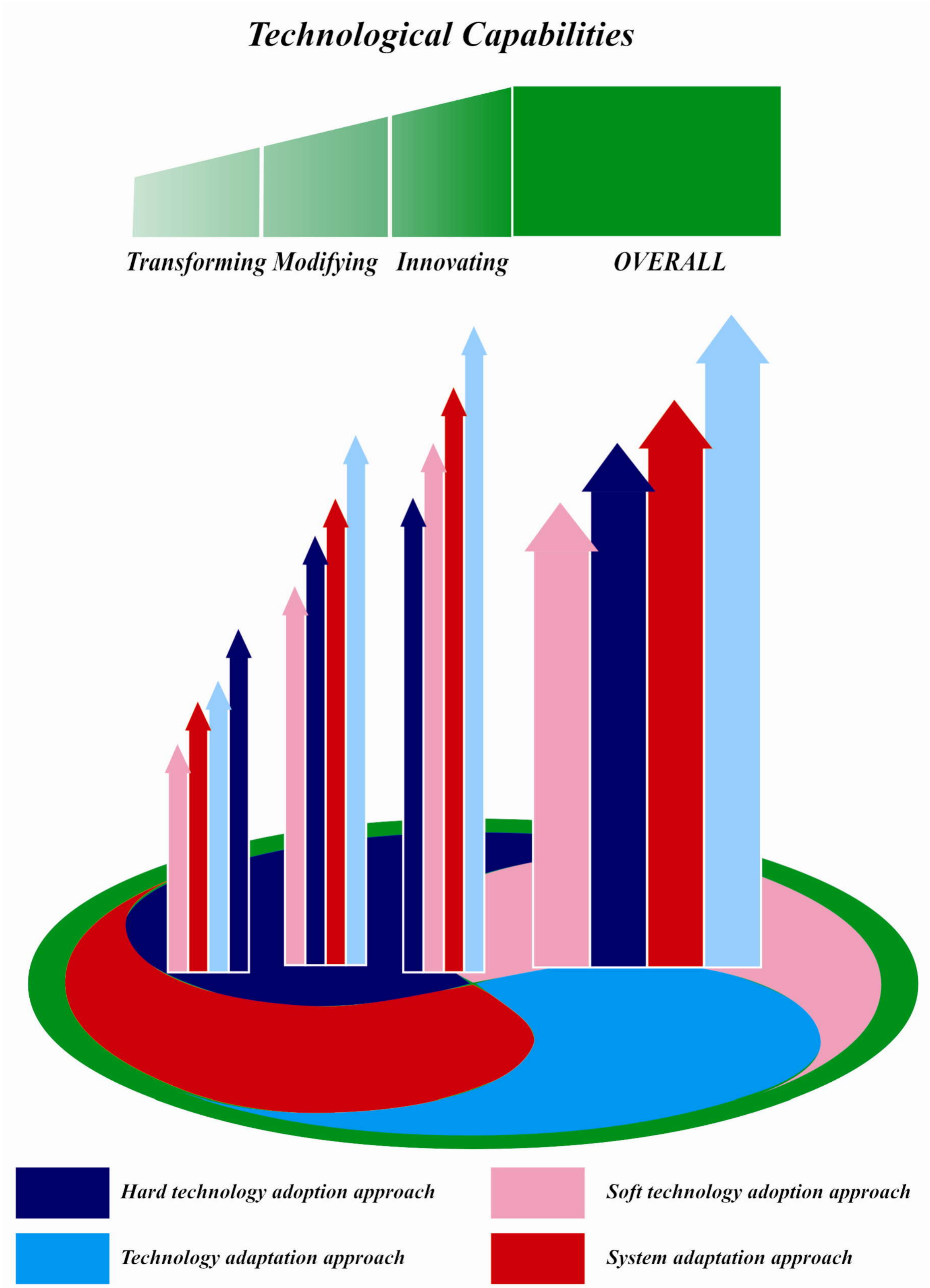

Figure 6.4 Approaches to technological capability building

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 methods 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. 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 status, need and potential of technology adoption and adaptation in Indian manufacturing industry and to evolve an approach to manage it flexibly for building technological capabilities and competitive advantages. Various phases of the study have been: clarifying the context through a detailed review of literature on flexibility, technology adoption and adaptation and technological capabilities; understanding and assessing the situation by conducting a survey of the manufacturing industry of north India to assess the status of technology adoption and adaptation, technological capability and flexibility introduced in it; analysis of the data collected through survey to establish the relationship between various independent and dependent constructs; assessing the actor's capability by conducting case studies in some of the surveyed industrial units; synthesis of the learning issues of survey and case studies; developing a management process for flexibly managing the technology adoption and adaptation in manufacturing industry; and finally recommending an implementation plan.

The survey was conducted through a specially designed questionnaire. The review of literature provided an insight into the various facets of technology adoption and adaptation, technological capability and flexibility, which was helpful in deciding the contents and the format of the questionnaire. The questionnaire was standardized after pre-testing. The survey was then carried by mail and through personal visits. From the survey, the status of 70 manufacturing organizations in the northern region of India, with respect to technology adoption and adaptation and technological capability, was found. The association between various independent constructs and technological capability, success and flexibility has been established using canonical correlation analyses and multiple regression analyses.

The purpose of the case studies has been to validate the results achieved from descriptive and empirical analysis of data of the survey.

To carry out case studies, the basis for selection of industrial units has been discussed in section 3.3.3. Accordingly, the case studies have been conducted in Maruti Suzuki India Limited (MSIL), Gurgaon; Sona Koyo Steering Systems Limited (SKSSL), Gurgaon; Moserbaer India Limited (MIL), Noida; and Punjab Tractors Limited (PTL), Mohali.

Various factors related to adoption and adaptation of technology as mentioned earlier are studied through case studies. Only those factors, which were reflected as the potential factors have been taken up for detailed study.

To build technological capabilities 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 was worked out to achieve the strategic success in manufacturing industry. The order of implementing various strategies to successfully manage new technology in Indian context has been highlighted.

7.3 RESULTS AND MAJOR LEARNINGS

The various learning issues have been derived on the basis of descriptive and empirical analyses of the primary data collected through the questionnaire survey. The following learning issues have been synthesized in the qualitative modeling for developing the implementation plan.

7.3.1 Learnings from the survey – Descriptive analyses

Concerning technology adoption

- Most of the companies have always been adopting new technology in the past to match their requirement.
- One third of the companies adopt new technology immediately on its availability and one sixth of the companies adopt only when there is dire need of it.
- Around 80% of the companies adopt new technology for some or more of the important processes.
- Around 89% of the companies consider the alternate process that can be developed in house for making new technology cost effective.
- Almost all the companies conduct some analysis based on the trends of the past years before going for new technology.
- All the companies go for economic viability study for adopting new technology.
- Around 86% of the companies considerably look into consequential changes in related products and processes, whereas 3% companies do not take any such consideration in account.
- Around 34% of the companies involve the manpower from the very beginning.
- The government through its agencies encourages 25% companies to adopt new technologies.
- 32% of the companies adopt new technology due to govt. regulations (environment or pollution related).
- Around 33% of the companies adopt new technology due to incentive provided by the govt. for the purpose.
- Most of the companies consider the opportunities or threats caused by the globalization as a justified reason to adopt new technology.
- The availability of new technology due to globalization is a significant factor for adopting new technology.
- Top management always provides full support in all companies for new technology adoption.

- Most of the companies have written formal manufacturing strategies which helps in their technology upgradations.
- Understanding the benefits of new technology assists in adoption in 87% companies.
- Well defined objectives of new technology helps in its adoption in 87% companies.
- Most of the companies have well defined technology adoption policies, though these policies are used to varying extents in companies.
- In most of the companies the technology adoption policies include training of the employees at all levels.
- These policies are updated regularly in only 60% companies.
- Technology adoption policies help in capability building of 63% companies.
- Human factor plays a crucial role in new technology adoption in all the companies.
- In-house engineers actively participate in new technology adoption in 90% of the companies.
- Aligning the attitude of employees towards objectives of new technology smoothens its adoption process in 93% of the companies.
- For adopting new technology, all companies use formal education and training programmes for employees at all levels.

Concerning technology adaptation

- In 63% companies, there is considerable need of redesigning production systems to achieve ergonomics and safety layout of machines whereas 50% of companies need some standardization of equipment.
- There is some need of redesigning the organization structure and considerable need of internal shifting of people in 63% companies.
- Almost all companies may need to recruit suitable persons from outside for successful adaptation of new technologies.
- There is considerable need of imparting training to personnel and designing new methods of performance and efficiency measurement.

- In 44% companies, considerable efforts have to be put in to make new technology acceptable to employees.
- Considerable changes in manufacturing, product design and features, plans and procedures and have to be implemented during technology adaptations.
- The effectiveness of the technology adaptation process can be considerably enhanced by empowerment, extensive training, open communication within the company, job security to employees and rewards and recognition.
- There is negligible role of govt. in adaptation of new technology.
- The top management provides support for technology adaptation and allocates sufficient funds for the same in all companies.
- Top management is also ready for taking short term risks in order to have long term pay offs in all companies.
- Skilled workers help in easy adaptation of new technology as compared to unskilled counterparts in 93% companies.
- Technocratization is found to be a key factor response for technology adaptation in 83% companies.
- In 84% companies, employees are willing to accept changes.
- Staffing flexibilities & production flexibility of company assists in technology adaptation.
- 83% companies indicate the importance of in-house R&D for new technology adaptation.
- Technology adaptation policies exist to some extent in 71% companies
- Wherever exist, these include training of employees, procedures and practices for smooth adaptation of technology.

Concerning technological capabilities

- 57% companies are aware of technology issues and the need to acquire technologies to a large extent.
- 81% companies have the ability to a large extent to seek out and identify technologies to solve particular problems.

- 73% companies have built distinctive capabilities to a large extent in some area of technology.
- 67 % companies can develop of a technology strategy, including a framework with priorities and an action plan.
- The ability to assess and select cost effective technology solutions is possessed to a large extent by 69% companies.
- 84% companies are carrying out the acquisition and absorption of specific technologies.
- Only 37% companies possess, to a large extent, the skills involved in making effective use of technology, whereas another 41% companies possess such skill to considerable extent.
- The ability to learn from and accumulate experience in order to continuously improve capabilities is possessed to a large extent by 73% companies.
- 60% companies possess the ability to considerable extent to form and exploit linkages with networks of technology suppliers and others involved in technology, whereas only 19% companies possess such abilities to a large extent.

Concerning technology adoption and adaptation policies

- 97.1 % companies have status of technology adoption policies fair or better as compared to 79.6 % companies in case of technology adaptation policies
- Technology adaptation policies have stronger impact on technological capabilities as compared to technology adoption policies.

Concerning critical barriers to new technology adoption

- The following are the critical barriers to new technology adoption (in order of importance):
    - Cost of training and education
    - Cost of new technology acquisition
    - Disruptions during implementation
    - Increased maintenance expenses
    - Workers' resistance.

Concerning critical barriers to new technology adaptation

- The following are the critical barriers to new technology adaptation (in order of importance):
    - Lack of in-house technical support
    - Adverse effect on work flow
    - Problems with compatibility of equipment

Concerning problems faced when existing and new technology are brought into contact

- The following problems are faced when existing and new technology are brought into contact (in order of importance):
    - Fear of lay-offs
    - Risk of production losses
    - Resistance to change
    - Difficulty in operating and maintaining new technology
    - Lack of co-operation and understanding

7.3.2 Learnings from the survey – Empirical analyses

Concerning correlation analyses

- Technological capabilities has a very strong and significant association with other dependent variables i.e. the success due to new technology ($r = 0.838$, $p = 0.000$) and flexibility ($r = 0.746$, $p = 0.000$).
- Further, the technological capabilities also have strong and significant association with impact of globalization ($r = 0.382$, $p = 0.001$); role of top management ($r = 0.353$, $p = 0.003$); manufacturing strategy and technology adoption policies ($r = 0.525$, $p = 0.000$); human factor ($r = 0.709$, $p = 0.000$); employees' education ($r = 0.478$, $p = 0.000$) and technology adaptation policies ($r = 0.400$, $p = 0.001$).
- Manufacturing strategy and technology adoption policy has very strong association with human factor ($r = 0.669$, $p = 0.000$) and technology adaptation policies ($r = 0.700$, $p = 0.000$).
- Role of government in technology adaptation has strong and significant association with role of government in technology adoption ($r = 0.649$, $p = 0.000$).

Concerning canonical correlation analyses

- The correlation between the variates (sets of independent variables and dependent variables) is found to be very high and significant ($r = 0.812$, $p = 0.000$, $r^2 = 0.659$) which implies that the 65.9% variation in the set of dependent variables can determined by the set of selected independent variables.
- Human factors in terms of their skill, technical expertise, training, involvement, attitude has the highest cross-loading (0.724) among the independent variate.
- Employees' education has come out to be second most significant factor affecting technological capabilities, success of technology adoption and adaptation and flexibility with cross loading of 0.499.

Concerning multiple regression analyses

- In multiple regression analysis using stepwise method, human factor, role of government in new technology adoption, employees' education, impact of globalization and role of top management in technology adaptation are found to be significant in the prediction of technological capability.
- Human factor, role of government in new technology adoption, employees' education, impact of globalization and role of top management in technology adaptation are found to be the significant factors in success due to technology adoption and adaptation through multiple regression analysis (using stepwise method)
- The results of stepwise multiple regression of flexibility indicates that human factor and employees' education are significant factors in the prediction of flexibility.

7.3.3 Learnings from the case studies

The learnings from various case studies conducted in various manufacturing units have been synthesized as follows:

Concerning technology adoption

- Adopt new technology to match the future requirement.
- Adopt new technology when its performance is proved.
- Adopt new technology for most of the important processes.

- Consider the alternate process that can be developed in house for making new technology cost effective.
- Conduct analysis based on the trends of the past years before going for new technology.
- Study economic viability of new technology and analyze its quantitative and qualitative effects.
- Consider consequential changes in related products and processes.
- Involve the manpower from the very beginning of adopting new technology.
- The government through its agencies should encourage companies to adopt new technologies.
- Government regulations (environment or pollution related) force companies to adopt new cleaner technologies.
- Industry policies should provide some incentives for cleaner technologies.
- Opportunities or threats caused by the globalization serve as a justified reason for adopting new technology.
- Availability of new technology due to globalization is a noteworthy factor for adopting new technology.
- Top management's full support is indispensable for new technology adoption.
- Formal manufacturing strategies must address to new technology adoption needs.
- Define objectives of new technology.
- Clarify the benefits of new technology.
- There should be well defined technology adoption policies in place and these must be thoroughly used.
- Include training of the employees at all levels in technology adoption policies
- Update these policies regularly.
- Human factor plays a crucial role in new technology adoption.
- Involve manpower in the process of new technology adoption
- In-house engineers to actively participate in new technology adoption.
- Align the attitude of employees towards objectives of new technology adoption.
- Plan formal education and training programmes for employees at all levels.

Concerning technology adaptation:

- For adapting to new technology, consider the need of redesigning the production systems to achieve ergonomics and safety layout of machines, standardization of equipment, effective use and presentation of controls and instrumentation and to ensure the smooth flow of materials.
- Consider the need of redesigning the organization structure, internal shifting of people and recruiting suitable persons from outside for successful adaptation of new technologies.
- There is considerable need of imparting training to personnel and designing new methods of performance and efficiency measurement.
- Put in efforts to make new technology acceptable to employees.
- Some changes in manufacturing, product design and features, plans and procedures have to be implemented during technology adaptations.
- The adaptability of a company for new technology is considerably affected by its staffing flexibility and production flexibility.
- The effectiveness of the technology adaptation process can be considerably enhanced by empowerment, extensive training, open communication within the company, job security to employees and rewards and recognition.
- There is little role of government in adaptation of new technology.
- The top management support is vital for technology adaptation and it should allocate sufficient funds for the same.
- Top management must be ready for taking short term risks in order to have long term pay offs in all companies.
- Skilled workers help in easy adaptation of new technology as compared to unskilled counterparts.
- Technocratization is a key factor responsible for technology adaptation.
- Employees' willingness to accept changes is beneficial for technology adaptation.
- There is a high importance of in-house R&D for new technology adaptation.
- There are hardly any well laid technology adaptation policies and wherever exist, these include training of employees, procedures and practices to some extent.

Concerning technological capabilities

- Be aware of role of technology in companies' competitiveness.

- Scan or monitor external technology events and trends.
- Define individual technological strengths and build up a unique advantage in specific area.
- Formulate a technology strategy as a key part of the overall business strategy.
- Gather information on range of technological options available, choose quickly among competing solutions and identify the most appropriate source which fits with the needs.
- Deploy the resources to exploit the selected technological option either by developing technology through in-house R&D or by acquiring it through a joint venture / technology licensing or otherwise.
- Implement the acquired technology which may involve various stages like its adaptation or reconfiguration.
- Review technology projects and processes within the firm in order to learn from success or failures.
- Maintain links with different kinds of external organizations which may provide them technology related services.
- Carry out continuous improvements in all technological related activities and components.
- Effectively utilize available technologies for transformation.
- Utilize the relevant technologies in distributing, selling or servicing its outputs.
- Utilize process development technologies in form of reverse engineering the acquired technology or with product / process innovations.

7.3.4 Summary of developing a management process

To achieve the projected requirements of building technological capabilities, 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 building technological capabilities. 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 flexibly managing technology adoption and adaptation have been finalized. These profiles are: hard technology adoption approach, soft technology adoption approach, technology adaptation approach and system adaptation approach. After deciding the profiles, various objectives of the industry have been decided. These objectives have been taken from the results of the survey conducted. These are: transforming capability, modifying capability and innovating capability. 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 manufacturing industry. Different approaches have been suggested to meet the future requirements of flexible management of technology adoption and adaptation building technological capabilities.

7.3.4 Summary of implementation plan

After developing the management process for flexibly managing technology adoption and adaptation in manufacturing industry for building technological capabilities, a 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 the case studies as well as the developed management process point out that **'technology adaptation approach'** is the key strategy to be followed for achieving technological capabilities in flexibly managing technology adoption and adaptation. Further **'system adaptation approach'**, and **'hard technology adoption approach'**, are the need of the hour in this globalized business. Just to be a part of this global technological business, the organizations hav to follow these three strategies seriously.

7.4 CONCLUSIONS AND RECOMMENDATIONS

This section points out conclusions, in a digest form, on each of the issues concerning technology adoption, adaptation and technological capabilities, that were raised at the beginning of this research work. This is followed by a summary of these as a response to the objective of carrying out this research, mentioned in chapter 1.

1. Manufacturing companies adopt new technology for their important processes, to match market requirements. The companies adopt new technology after its performance is established. The companies carry out economic viability studies before adopting new technology and also consider alternate processes that can be developed in-house for making it cost effective. The companies emphasize more on technology adoption than on its adaptation.
2. Flexible management of technology adoption in manufacturing companies is affected by role of government; impact of globalization; role of top management; manufacturing strategies and technology adoption policies of the company; and human factor. Flexible management of technology adaptation is affected by role of government; role of top management; employees' skill, education and attitude; in-house R&D; and technology adaptation policies of the company.
3. Human factor; employees' skill, education and attitude; and impact of globalization are significant factors positively correlated to technological capabilities; whereas the role of government in technology adoption and role of top management in technology adaptation are also significant, but negatively correlated to it. Human factor and employees' skill, education and attitude are significant factors affecting overall flexibility.
4. Technology adoption policies are well defined in manufacturing companies, whereas technology adaptation policies are rare. Similar status has been found for updation of these policies. Technological capabilities have small, positive but significant association with technology adoption and adaptation policies. However, the association of technological capabilities with technology adaptation policies is stronger and more significant as compared to their association with the technology adoption policies.
5. Retrenchment, production losses, resistance to change, operation and maintenance, and non-cooperation by staff are severe problems faced in manufacturing companies, when old and new technologies are brought into

contact. Cost of training and education, cost of new technology acquisition, disruptions during implementation, increase in maintenance expenses, and workers' resistance have been found to be major barriers to new technology adoption in the companies. Lack of in-house technical support, adverse effect on work flow, and incompatible equipment have been found to be major barriers to new technology adaptation. Various strategies and actions have been suggested for overcoming above-mentioned barriers.

6. Four types of flexible approaches – technology adaptation approach, system adaptations approach, hard technology adoption approach, and soft technology adoption approach – have been identified for developing technological capabilities. Their combinations are recommended for developing (a) transforming (b) modifying and (c) innovating capabilities.

7.5 LIMITATIONS OF THE STUDY

The main limitations of this study are as follows:

- The study has been limited to medium and large scale manufacturing organizations in northern region of India.
- All manufacturing organizations have been treated alike, irrespective of the specific requirements of various sectors.
- As such no mathematical model or equation has been derived to calculate the contribution of flexibility to technology adoption and adaptation, and then to technological capabilities.

7.6 SCOPE FOR FUTURE WORK

While carrying out this study and trying to list its scope, a number of areas have 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 present study has concentrated on manufacturing industry only. The work should be extended to other categories of industry like service industry.
- All manufacturing organizations have been treated alike, irrespective of the specific requirements of various sectors. Minor changes might have to be incorporated to effectively build technological capabilities in varying situations.

Thus, sectors wise analysis can also be conducted for appropriately dealing with varying requirements of different sectors.

- The present study has suggested a management process for flexible management of new technology in manufacturing industry for building technological capabilities. Certain strategies have been proposed which call for studies at micro level e.g., type of education and training to be provided to the employee at different levels to develop their skills and capabilities to utilize the new technology to the maximum, enrichment of the job, providing motivation and encouragement to the workers, introducing flexi-timings and incentives for higher and quality production.
- The item measures identified for various constructs have been considered to be equally important in the study, however in real life situations, some item measures may be more important than the others. This study can be extended by attaching appropriate weights to these item measures through qualitative techniques.
- Similar studies may be conducted on other phases of technology management also, to see their effects on building technological capabilities.

7.7 CONCLUDING REMARKS

Based on the conclusions derived on each issue identified at the beginning of the research, the present status of technology adoption is fairly good in India. The status and pace of technology adaptation is not good enough in the Indian manufacturing industry. The new technology is generally adopted in the organizations to replace existing technologies and then adapted to suit local environment. Domain of human factor and employees' education for overall flexibility are seriously dealt with in the manufacturing industry. Technology adaptation policies and their updation are not considered seriously by the manufacturing industry. Overall technology adoption and adaptation for building technological capabilities in the Indian manufacturing industry is satisfactory, but at the same time, it also has a lot of scope for further improvements for facing the challenge of local and global competition.

It is concluded that in this modern age, adoption and adaptation of new technologies are needed to gain competitive edge in the global market. Flexible management of the same shall lead the organizations to build their technological capabilities for not only surviving but also thriving in the technology-intensive industrial environment around the globe.

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APPENDIX – A

DEPARTMENT OF MECHANICAL ENGINEERING
Thapar Institute of Engineering and Technology
(Deemed University) PATIALA
www.tiet.ac.in

To,

Subject: Request for responding to the survey on Technology Adoption and Adaptation.

Dear Sir,

You would be glad to know that cutting edge topics of new technology adoption, adaptation and capability building in manufacturing industry is being researched upon in Thapar Institute of Engineering and Technology, Patiala.

Myself, ***Amanpreet Singh Sethi***, working as ***Assistant Professor and Head***, Mechanical Engineering Department, BBSB Engineering College, Fatehgarh Sahib (***www.bbsbec.org***). My area of research is Technology adoption and adaptation and its relation with Technological Capability of the industry. I am conducting a survey on this topic as apart of my ***Ph.D. research work*** entitled ***"Flexible Management of Technology Adoption and Adaptation in Manufacturing Industry"*** at Thapar Institute of Engineering and Technology, Patiala under the supervision of ***Dr. J.S. Khamba*** (Professor and Head, Mechanical engineering Department, University College of Engineering, Punjabi University, Patiala) and ***Dr. Sushil*** (Professor, Department of Management Studies, Indian Institute of Technology, Delhi).

The objective of my Ph.D. research work is: "To analyze the technology adoption and adaptation processes used in manufacturing industry and to develop a framework representing the linkages of technology adoption and adaptation with capability building of these companies." It is being sent to decision makers who are at senior and medium levels of management, dealing with the process of new technology adoption or adaptation with ultimate motive of developing technological capabilities.

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. In case you need clarification or further information related to any of the questions, kindly contact me via email or mobile, quoting the question number. I would be happy to provide you further information or discuss in detail with you the concerned questions.

I shall ever remain grateful to you for your help and co-operation in this regard. I will be happy to provide you with a electronic/printed copy of the findings of this study that could be helpful to you in the assessment the level of technological capability in your organization. I assure you that your responses will be held strictly 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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A few definitions for terms used in questionnaire:

New Technology:

A product or process that a company has not previously used or Technology from R&D laboratories that have yet not been used by a company even once.

Technology Adoption

It refers to the process by which a new technology is selected for the company to have a short term or long-term payoff in higher profits.

Technology Adaptation

It aims at making the adopted processes and products more effective in the local environment. It includes:

Modifications and alterations to suit the indigenous conditions
Scaling up or scaling down operations
Modifications from ergonomic and economic viewpoints
Manufacturing systemization etc.

Technological Capability

It refers to the ability to make effective use of technological knowledge to assimilate, use, adapt and change existing technologies. It also enables one to create new technologies and to develop new products and processes in response to the changing economic environment

QUESTIONNAIRE

SECTION A: GENERAL

COMPANY NAME				
COMPANY ADDRESS				
Survey respondent’s name and designation				
Respondent’s e-mail address and contact number				
Main product(s) of the company				
Accreditations / Certifications of the company				
Collaboration with some foreign company, if any				
Approximate Number of Employees	Managerial/ Supervisory: _______________Workers_________________			
	No. of Engineers/Technicians: ______________			
Present turnover (Rupees in crores)	< 100	101 – 250	251 –500	> 500
Market share	< 10%	11 - 25%	26 - 50%	> 51 %
Net profit (as percentage of turnover)	< 5%	6 to 10%	11 to 20%	> 20%

A1. What have been the expectations of your company after successfully adopting and adapting the new technology? Please prioritize them. (Highest priority 1)

	Expectation	**Priority (1 to 7)**
i.	Increased Sales	
ii.	Increased Net profit	
iii.	Increased Market Share	
iv.	Improved productivity	
v.	Improved Product Quality	
vi.	Reduced Product Cost	
vii.	Increased Competitiveness	

A2. Investment made in the following areas as percentage of total expenditure during last year. (Please tick)

i.	New machinery and Equipment	1 to 20	21 to 40	41 to 60	> 60
ii.	Computer hardware and software	1 to 10	11 to 20	21 to 30	> 30
iii.	Research and Development	1 to 10	11 to 20	21 to 30	> 30
iv.	Books, Journals and other literature	1 to 5	6 to 10	11 to 15	> 15

A3. Characteristics of the company:

i.	How old is your company? (Years)	1 – 5	6 - 10	11 – 15	> 15
ii.	What is the organizational status of your plant?	Head Office	Branch	Independent Unit	Ancillary
iii.	What is the status of union of employees in your plant?	Very strong	Moderately strong	Not so strong	Weak
iv.	What type of production is there in your plant?	Continuous	Mass	Batch	Job order
v.	Number of main competitors in market	0	1 to 5	6 to 10	>10
vi.	Is your company located in the cluster of similar industries?	**Not at all 1**	**To some extent 2**	**Considerable extent 3**	**To a large extent 4**
vii.	Is your company located near the big cities?	1	2	3	4
viii.	Does your company export its products or look for new markets?	1	2	3	4
ix.	Does your company participate in inter-company groups and networks?	1	2	3	4
x.	Is your company also engaged in rework and remanufacturing?	1	2	3	4
xi.	Does your company seek advice from customers for various improvements?	1	2	3	4
xii.	Does your company avails assistance from Governmental R&D organizations?	1	2	3	4
xiii.	Does your company has the capability of Manufacturing Process Re-engineering?	1	2	3	4

SECTION – B: TECHNOLOGY ADOPTION

B1.	Have you been adopting new technology in the past to match market requirements?	Rarely	Sometimes	Normally	Always
B2.	When had you adopted new technology for the first time?	Less than 1 year back	1 to 5 years back	5 to 10 years back	More than 10 years back
B3.	How many times have you adopted new technology?	1 to 3	3 to 5	5 to 10	More than 10
B4.	At present, which technology are you using?	Quite old	Conventional	Intermediate	Advanced
B5.	When do you decide to adopt new technology?	In dire need.	After its performance is proved	When it is getting popular	Immediately on availability.
B6.	Do you consider the alternate processes that can be developed in-house for making new technology cost effective?	Not at all	To some extent	To considerable extent	To large extent.
B7.	For which process of your plant, you adopt new technologies?	Most critical processes	Some of the important processes	Most of the important processes	Covering all processes and operations
B8.	Do you conduct some analysis based on the trends of the past years before going for new technology?	No analysis is conducted	Some inferences are used	Past trends are made use of	Extensive analysis is conducted
B9.	For adopting new technology, do you go in for economic viability study?	No formal analysis is done.	Only effects are considered	Quantitative effects analyzed in detail.	Quantitative and Qualitative effects analyzed in detail.
B10.	Before adopting new technology, do you consider consequential changes in related products and process?	Not considered at all	Some consideration is given	Considered in general	Considered in detail and alternatives planned
B11.	For adopting new technology, how do you manage the manpower?	Get prepare to meet any situation	Try to convince employees, if needed.	Pass on some information to employees	Involve them from very beginning.

B12. You go in for (or decide to go in for) new technology: (please tick, more than one option is possible).

a. when your profit margins start shrinking and you are not able to maintain the quality levels and production rates.
b. when new technology becomes so well known that everybody acquires it, you also follow.
c. when you read about new developments in the journals/papers and plan to acquire new technology to try and test.
d. when your officials visit foreign locations to get new ideas to develop new technologies in-house.

B13. To what extent do you agree with the following statements concerning new technology adoption?

		Disagree **1**	**Neutral** **2**	**Agree** **3**	**Strongly agree** **4**
Impact of Globalization					
i.	Opportunities created due to globalization in form of vast international markets encouraged you to go for new technology	1	2	3	4
ii.	Threats caused due to globalization in form of big competitors in your markets, force you to go for new technology.	1	2	3	4
iii.	Availability of better technology due to globalization attracted you to go for it	1	2	3	4
Role of Government					
iv.	Govt agencies encourage new technology adoption	1	2	3	4
v.	Govt regulations (environmental related etc) force you to go for new technology adoption	1	2	3	4
vi.	Industrial policy provides incentives for new technology adoption.	1	2	3	4
Role of Top Management					
vii.	Top management support is one of the key factors for new technology adoption	1	2	3	4
viii.	Top management must be ready for short term risks for long term improvements	1	2	3	4
ix.	Top management must allocate proper funds for new technology adoption	1	2	3	4
Manufacturing Strategy					
x.	A written formal Manufacturing Strategy certainly helps in new technology adoption.	1	2	3	4
xi.	Proper understanding of current operations assists in new technology adoption.	1	2	3	4
xii.	Understanding of benefits of new technology helps in its adoption.	1	2	3	4
xiii.	The presence of well defined objectives of new technology aids in its successful adoption.	1	2	3	4
Technical Expertise					
xiv.	Active participation from in-house engineers plays a positive role in new technology adoption.	1	2	3	4
xv.	Availability of Professional Consultants helps in new technology adoption	1	2	3	4
Vendors' Participation					
xvi.	Cordial relationships with the suppliers of technology results in its successful adoption.	1	2	3	4
xvii.	The selection of appropriate supplier of technology affects its process of adoption.	1	2	3	4

		Disagree 1	Neutral 2	Agree 3	Strongly agree 4
Training of Employees					
xviii.	Aligning the attitude of employees towards objectives of new technology adoption helps in its easy adoption.	1	2	3	4
xix.	Formal Education and training programmes should be developed to include all classes of users ranging from top management to shop floor controllers.	1	2	3	4

B14. To what extent you agree with the following statements concerning technology adoption policies?

	ISSUES	Disagree 1	Neutral 2	Agree 3	Strongly agree 4
i.	Your company has well laid technology adoption policies.	1	2	3	4
ii.	Your company extensively and thoroughly uses these technology adoption policies	1	2	3	4
iii.	The adoption policies include training of the employees at all levels.	1	2	3	4
iv.	The adoption policies include procedures and practices for capability building of your plant	1	2	3	4
v.	Your adoption policies updated and reviewed periodically.	1	2	3	4
vi.	Your company tracks technology adoption costs?	1	2	3	4
vii.	These adoption policies help in capability building of your plant.	1	2	3	4

B15. Please indicate the importance of the following barriers to new technology adoption in your company.

BARRIERS TO NEW TECHNOLOGY ADOPTION		Not at all important 1	Neutral 2	Important 3	Highly important 4
i.	Cost of new technology acquisition	1	2	3	4
ii.	Cost of training and education	1	2	3	4
iii.	Problems with compatibility of equipment	1	2	3	4
iv.	Skill deficiency for new technology	1	2	3	4
v.	Production management skill deficiency	1	2	3	4
vi.	Disruptions during implementation	1	2	3	4
vii.	Adverse effect on work flow	1	2	3	4
viii.	Risk of failure to achieve financial targets	1	2	3	4
ix.	Inadequate flexibility in regulations	1	2	3	4
x.	Lack of customers’ responsiveness to new products	1	2	3	4
xi.	Workers’ resistance	1	2	3	4
xii.	Increased maintenance expenses	1	2	3	4
xiii.	Need for market expansion	1	2	3	4
xiv.	Lack of financial justification	1	2	3	4
xv.	Lack of qualified personnel	1	2	3	4
xvi.	Lack of information on technology	1	2	3	4
xvii.	Lack of information on markets	1	2	3	4
xviii.	Lack of support from vendors	1	2	3	4
xix.	Lack of marketing capabilities	1	2	3	4
xx.	Organizational rigidities within enterprise	1	2	3	4
xxi.	Lack of appropriate sources of finance	1	2	3	4
xxii.	Inability to devote staff to projects	1	2	3	4
xxiii.	Lack of industry wide standards	1	2	3	4
xxiv.	Likely obsolescence of technology	1	2	3	4

B16. What kind of problems you face, when the old and new technologies are brought into contact:

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Risk of production loss				
ii.	Lack of knowledge about new technology	1	2	3	4
iii.	Difficulty in operating and maintaining new technology	1	2	3	4
iv.	Lack of co-operation and understanding	1	2	3	4
v.	Fear of Layoffs	1	2	3	4
vi.	Resistance to change	1	2	3	4
vii.	Lack of action oriented strategies	1	2	3	4
viii.	Inadequate internal skills	1	2	3	4
ix.	Lack of motivation	1	2	3	4
x.	Lack of management information system	1	2	3	4
xi.	Inability to migrate to new technology	1	2	3	4
xii.	Lack of proper infrastructure	1	2	3	4

B17. To what extent, are you satisfied with the results achieved after the adoption of new technology in your company?

Not at all	to some extent	to a considerable extent	Fully satisfied

SECTION – C: TECHNOLOGY ADAPTATION

C1. For adapting new technology, do you have to redesign your production system to achieve:

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Satisfactory ergonomic and safety layout of machines?				
ii.	Standardization of equipment?	1	2	3	4
iii.	Effective use and presentation of controls and instrumentations?	1	2	3	4
iv.	Smooth flow of material	1	2	3	4

C2. For adapting new technology, do you have to:

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	redesign your organizational structure?				
ii.	shift people within the company?	1	2	3	4
iii.	recruit suitable persons from outside?	1	2	3	4
iv.	impart training to personnel?	1	2	3	4
v.	devise new methods of performance and efficiency measurement?	1	2	3	4
vi.	put efforts to make the new technology acceptable to employees?	1	2	3	4

C3. Upto what extent, are the following measures implemented for successful adaptation of new technology?

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Changes in manufacturing				
ii.	Changes in product design and features	1	2	3	4
iii.	Changes in plans and procedures	1	2	3	4
iv.	Changes in reliability	1	2	3	4

C4. To what extent you agree with the following statements concerning new technology adaptation?

		Disagree 1	Neutral 2	Agree 3	Strongly agree 4
i.	Government supported you in your technology adaptation efforts through its initiatives and control.				
ii.	Top management support is one of the key factors for new technology adaptation.	1	2	3	4
iii.	Top management must be ready for short term risks for long term improvements.	1	2	3	4
iv.	Top management must allocate proper funds for new technology adaptation.	1	2	3	4
v.	Overall higher education level of employees facilitates the technology adaptation.	1	2	3	4
vi.	Skilled workers help in easy adaptation as compared to unskilled.	1	2	3	4
vii.	Total number of engineers and technicians in the company is a key factor responsible for technology adaptation.	1	2	3	4
viii.	In-house R&D is a must for smooth adaptation of technology within the company.	1	2	3	4
ix.	People in your company are willing to accept changes.	1	2	3	4
x.	Technology content has an important bearing on the technology adaptation.	1	2	3	4
xi.	The adaptive ability of an company for a new technology is affected by its staffing flexibility and production flexibility.	1	2	3	4

C5. To what extent do you agree with the following statements concerning technology adaptation policies?

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Your company has well laid technology adaptation policies.				
ii.	Your company extensively and thoroughly uses these technology adaptation policies	1	2	3	4
iii.	The adaptation policies include training of employees at all levels.	1	2	3	4
iv.	The adaptation policies include procedures and practices for smooth adaptation of new technology	1	2	3	4
v.	Your company records adaptation information into equipment history	1	2	3	4
vi.	Your adaptation policies updated and reviewed periodically.	1	2	3	4
vii.	These adaptation policies help in capability building of your plant.	1	2	3	4

C6. The effectiveness of technology adaptation process can be increased by:

		Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Empowerment *(giving workers more responsibility and control of the manufacturing process)*				
ii.	Extensive training	1	2	3	4
iii.	Open communication within organization	1	2	3	4
iv.	Job security	1	2	3	4
v.	Rewards and recognition	1	2	3	4

C7. Please indicate the importance of the following barriers to new technology adaptation in your company.

BARRIERS TO NEW TECHNOLOGY ADAPTATION		Not at all important 1	Neutral 2	Important 3	Highly important 4
i.	Problems with compatibility of equipments	1	2	3	4
ii.	Adverse effect on work flow	1	2	3	4

	BARRIERS TO NEW TECHNOLOGY ADAPTATION	Not at all important 1	Neutral 2	Important 3	Highly important 4
iii.	Inadequate flexibility in regulations	1	2	3	4
iv.	Lack of in-house technical support	1	2	3	4
v.	Lack of information on technology	1	2	3	4
vi.	Lack of support from vendors	1	2	3	4
vii.	Organizational rigidities within enterprise	1	2	3	4
viii.	Lack of industry wide standards	1	2	3	4

C7. To what extent are you satisfied with the results achieved after the adaptation of new technology in your company?

Not at all	to some extent	to a considerable extent	Fully satisfied

SECTION – D: TECHNOLOGICAL CAPABILITY

D1. Technological Capability Audit: The following table is intended to assess the present status of Technological Capability of your company.

	ISSUES	Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Is your company well aware of the technologies most important to its business?	1	2	3	4
ii.	Does technology play an important part in your company's business strategy?	1	2	3	4
iii.	Is your company well equipped to assess technological opportunities?	1	2	3	4
iv.	Can your company assess technology threats without difficulty?	1	2	3	4
v.	Does your company has special technological strengths which it is able to exploit?	1	2	3	4
vi.	Does your company knows which technologies to outsource and which to develop internally?	1	2	3	4
vii.	Is your management skilled at formulating a technology strategy to meet business goals?	1	2	3	4
viii.	Does your company know its main technology priorities?	1	2	3	4
ix.	Does your company has a well developed technology 'vision'?	1	2	3	4
x.	Does your company know how to select the technology needed for its business?	1	2	3	4
xi.	Does your company know the best sources of technology?	1	2	3	4
xii.	Is your company effective at acquiring technology from external sources?	1	2	3	4
xiii.	Does your company have good links with important external suppliers of technology?	1	2	3	4
xiv.	Are your technology activities (e.g. engineering and R&D) organized effectively within company?	1	2	3	4
xv.	Do you have clear processes for carrying out technology projects?	1	2	3	4
xvi.	Does your company have a good system for assessing technology projects?	1	2	3	4
xvii.	Does your company carries out post-project reviews?	1	2	3	4
xviii.	Are you able to learn from one technology project to another?	1	2	3	4
xix.	Do Government policies encourage you to invest in technology?	1	2	3	4
xx.	Do you use external organizations (e.g. consultancy firms) to assist you with technology assessment?	1	2	3	4
xxi.	Do you use outside bodies to help you develop technology?	1	2	3	4

	ISSUES	Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
xxii.	Do the external organizations help you in implementing your technology strategy?	1	2	3	4
xxiii.	Do you work with universities in key technology projects?	1	2	3	4
xxiv.	Do you work with government research institutes in important technology projects?	1	2	3	4

D2. How far have you been able to achieve the following objectives by adoption and adaptation of new technology in your company?

	Objectives	Not at all 1	To some extent 2	Considerable extent 3	To a large extent 4
i.	Increased ability to change production lot sizes;	1	2	3	4
ii.	Increased variety of part-types or products manufactured;	1	2	3	4
iii.	Increased average number of tasks performed by an operator;	1	2	3	4
iv.	Increased operator output rates;	1	2	3	4
v.	Increased plant revenues from manufacturing operations;	1	2	3	4
vi.	Reduced delivery lead times;	1	2	3	4
vii.	Reduced overhead costs;	1	2	3	4
viii.	Improved product quality;	1	2	3	4
ix.	Increased inventory turnover rates;	1	2	3	4
x.	Reduced production change-over times;	1	2	3	4
xi.	Reduced time needed for a major change in an existing product;	1	2	3	4
xii.	Reduced time-to-market for a new product	1	2	3	4

SECTION – E: CONCLUSIONS

E1. As a concluding remark please indicate, how far you have been able to meet the following expectations after enhancing the technological capability of your company:

i.	Sales	Decreased 1	Remained the same 2	Marginally Increased 3	Substantially increased 4
ii.	Net profit	1	2	3	4
iii.	Market Share	1	2	3	4
iv.	Productivity	1	2	3	4
v.	Product Quality	1	2	3	4
vi.	Product Cost	1	2	3	4
vii.	Competitiveness	1	2	3	4

Seal of Company

Signature of Respondent

THANKS FOR YOUR CO-OPERATION

APPENDIX – B

Descriptive Statistics

Company	IP-11	IP-12	IP-13	IP-14	IP-15	IP-21	IP-22	IP-23	IP-24	IP-25	TC	SCS	FLX
1	0.833	0.500	1.000	0.808	0.938	0.500	0.918	0.850	0.750	0.678	0.740	0.875	0.750
2	0.918	0.750	0.833	0.865	0.938	0.500	1.000	0.750	1.000	0.823	0.783	0.773	0.645
3	0.833	0.750	0.668	0.750	0.813	0.500	0.583	0.650	1.000	0.573	0.668	0.628	0.685
4	0.750	0.418	1.000	0.750	0.938	0.500	1.000	0.750	0.750	0.500	0.605	0.460	0.685
5	1.000	0.250	1.000	0.770	0.813	0.250	1.000	0.800	0.750	0.608	0.688	0.563	0.750
6	0.668	0.500	0.668	0.673	0.688	0.750	0.668	0.700	0.750	0.608	0.615	0.443	0.620
7	0.833	0.668	0.833	0.885	0.875	0.250	0.833	0.750	0.500	0.678	0.750	0.833	0.663
8	1.000	0.668	0.918	0.750	0.938	0.750	0.750	0.800	0.750	0.823	0.928	0.960	0.663
9	0.583	0.418	0.750	0.750	0.875	0.250	1.000	0.900	0.500	0.750	0.708	0.665	0.678
10	0.668	0.250	1.000	0.730	0.875	0.250	1.000	1.000	1.000	0.573	0.740	0.750	0.718
11	0.750	0.583	0.833	0.730	0.813	0.500	1.000	0.850	0.750	0.823	0.813	0.813	0.710
12	0.918	0.583	1.000	0.845	1.000	0.500	0.833	0.850	0.750	0.823	0.688	0.583	0.678
13	1.000	0.500	1.000	0.713	0.938	0.500	1.000	0.800	0.750	0.500	0.688	0.480	0.663
14	0.583	0.918	1.000	0.770	1.000	1.000	1.000	0.950	0.750	0.573	0.908	0.963	0.775
15	1.000	0.833	0.833	0.845	0.938	0.500	1.000	0.850	0.750	0.500	0.823	0.925	0.790
16	0.750	0.250	1.000	0.808	1.000	0.250	1.000	0.800	0.500	0.500	0.813	0.645	0.783
17	0.750	0.583	1.000	0.865	0.938	0.500	1.000	0.850	0.500	1.000	0.918	0.835	0.830
18	0.750	0.668	1.000	0.905	1.000	0.500	0.918	0.800	0.750	0.823	0.750	0.875	0.703
19	0.668	0.500	0.750	0.788	0.875	0.250	0.750	0.700	0.500	0.823	0.720	0.753	0.710
20	1.000	0.918	1.000	0.923	0.875	0.500	0.833	0.800	0.750	0.893	0.750	0.708	0.783
21	0.500	0.250	0.750	0.405	0.750	0.250	0.750	0.650	0.750	0.250	0.563	0.708	0.515
22	0.750	0.500	0.583	0.808	0.938	0.250	1.000	0.850	0.750	0.608	0.750	0.730	0.743
23	0.918	0.500	1.000	0.770	0.938	0.250	1.000	0.800	0.750	0.750	0.658	0.523	0.743
24	0.833	0.333	1.000	0.595	0.688	0.250	0.918	0.850	1.000	0.500	0.490	0.438	0.493
25	1.000	0.918	1.000	0.845	1.000	0.500	0.918	0.900	1.000	0.785	0.813	0.730	0.888
26	1.000	0.500	0.833	0.750	0.813	0.500	0.833	0.900	1.000	0.573	0.770	0.770	0.838
27	0.750	0.500	1.000	0.750	0.750	0.500	1.000	0.850	0.750	0.573	0.533	0.375	0.718
28	0.418	0.500	1.000	0.595	0.563	0.500	1.000	0.800	0.750	0.573	0.543	0.605	0.620
29	0.418	0.250	0.750	0.655	0.438	0.500	0.833	0.600	0.500	0.428	0.428	0.293	0.475
30	0.250	0.250	0.833	0.538	0.438	0.250	0.833	0.750	0.750	0.500	0.543	0.605	0.573
31	0.418	0.418	1.000	0.693	0.938	0.500	0.918	0.850	0.750	0.500	0.918	0.918	0.808
32	0.418	0.583	0.750	0.558	0.750	0.750	1.000	0.700	0.750	0.500	0.553	0.523	0.565
33	0.833	0.583	0.918	0.770	0.938	0.500	1.000	0.850	0.750	0.535	0.813	0.750	0.848
34	0.750	0.333	1.000	0.673	0.875	0.250	1.000	0.750	0.750	0.500	0.760	0.853	0.815
35	0.833	0.333	0.833	0.595	0.813	0.500	0.750	0.750	0.750	0.500	0.740	0.688	0.783
36	0.583	0.418	0.833	0.673	0.750	0.500	0.750	0.700	0.750	0.500	0.760	0.853	0.808
37	0.250	1.000	1.000	0.788	0.813	1.000	1.000	0.650	0.750	0.715	0.803	0.913	0.808
38	0.583	0.833	1.000	0.578	0.875	0.750	1.000	0.700	0.500	0.500	0.803	0.750	0.765

Company	IP-11	IP-12	IP-13	IP-14	IP-15	IP-21	IP-22	IP-23	IP-24	IP-25	TC	SCS	FLX
39	0.668	0.500	0.833	0.538	0.688	0.500	0.833	0.600	0.750	0.500	0.500	0.458	0.548
40	0.668	0.583	1.000	0.578	0.813	0.250	1.000	0.750	0.750	0.500	0.783	0.753	0.808
41	0.418	0.250	1.000	0.750	0.875	0.500	0.918	0.850	0.750	0.573	0.783	0.913	0.838
42	0.833	0.500	0.833	0.615	0.750	0.500	0.833	0.850	0.750	0.500	0.668	0.543	0.765
43	0.833	0.500	1.000	0.808	0.938	0.500	0.918	0.850	0.750	0.678	0.740	0.875	0.750
44	0.918	0.750	0.833	0.865	0.938	0.500	1.000	0.750	1.000	0.823	0.783	0.773	0.645
45	0.833	0.750	0.668	0.750	0.813	0.500	0.583	0.650	1.000	0.573	0.668	0.628	0.685
46	0.750	0.418	1.000	0.750	0.938	0.500	1.000	0.750	0.750	0.500	0.605	0.460	0.685
47	1.000	0.250	1.000	0.770	0.813	0.250	1.000	0.800	0.750	0.608	0.688	0.563	0.750
48	0.668	0.500	0.668	0.673	0.688	0.750	0.668	0.700	0.750	0.608	0.615	0.423	0.620
49	1.000	0.668	0.918	0.750	0.938	0.750	0.750	0.800	0.750	0.823	0.928	0.960	0.663
50	0.583	0.418	0.750	0.750	0.875	0.250	1.000	0.900	0.500	0.750	0.708	0.665	0.678
51	0.750	0.583	0.833	0.730	0.813	0.500	1.000	0.850	0.750	0.823	0.813	0.813	0.710
52	1.000	0.500	1.000	0.713	0.938	0.500	1.000	0.800	0.750	0.500	0.688	0.480	0.663
53	0.583	0.918	1.000	0.770	1.000	1.000	1.000	0.950	0.750	0.573	0.908	0.950	0.775
54	0.750	0.250	1.000	0.808	1.000	0.250	1.000	0.800	0.500	0.500	0.813	0.645	0.783
55	0.750	0.583	1.000	0.865	0.938	0.500	1.000	0.850	0.500	1.000	0.918	0.835	0.830
56	0.668	0.500	0.750	0.788	0.875	0.250	0.750	0.700	0.500	0.823	0.720	0.753	0.710
57	0.918	0.500	1.000	0.770	0.938	0.250	1.000	0.800	0.750	0.750	0.658	0.523	0.743
58	1.000	0.918	1.000	0.845	1.000	0.500	0.918	0.900	1.000	0.785	0.813	0.730	0.888
59	1.000	0.500	0.833	0.750	0.813	0.500	0.833	0.900	1.000	0.573	0.770	0.770	0.838
60	0.250	0.250	0.833	0.538	0.438	0.250	0.833	0.750	0.750	0.500	0.543	0.605	0.573
61	0.418	0.418	1.000	0.693	0.938	0.500	0.918	0.850	0.750	0.500	0.918	0.918	0.808
62	0.418	0.583	0.750	0.558	0.750	0.750	1.000	0.700	0.750	0.500	0.553	0.523	0.565
63	0.833	0.583	0.918	0.770	0.938	0.500	1.000	0.850	0.750	0.535	0.813	0.750	0.848
64	0.583	0.418	0.833	0.673	0.750	0.500	0.750	0.700	0.750	0.500	0.760	0.853	0.808
65	0.250	1.000	1.000	0.788	0.813	1.000	1.000	0.650	0.750	0.715	0.803	0.980	0.808
66	0.583	0.833	1.000	0.578	0.875	0.750	1.000	0.700	0.500	0.500	0.803	0.750	0.765
67	0.668	0.500	0.833	0.538	0.688	0.500	0.833	0.600	0.750	0.500	0.500	0.458	0.548
68	0.418	0.250	1.000	0.750	0.875	0.500	0.918	0.850	0.750	0.573	0.783	0.960	0.838
69	0.833	0.500	0.833	0.615	0.750	0.500	0.833	0.850	0.750	0.500	0.668	0.543	0.765
70	0.418	0.418	1.000	0.693	0.938	0.500	0.918	0.850	0.750	0.500	0.918	0.918	0.808
Mean	0.714	0.537	0.901	0.726	0.847	0.489	0.908	0.789	0.743	0.618	0.728	0.705	0.723
Standard Deviation	0.216	0.204	0.117	0.106	0.130	0.197	0.114	0.089	0.141	0.148	0.121	0.173	0.097
Variance	0.186	0.167	0.054	0.045	0.068	0.155	0.052	0.032	0.080	0.088	0.058	0.120	0.038
Skewness	-0.121	0.131	-0.193	-0.156	-0.356	0.202	-0.271	-0.060	-0.003	0.160	-0.094	-0.068	-0.156
Range	0.750	0.750	0.418	0.518	0.563	0.750	0.418	0.400	0.500	0.750	0.500	0.688	0.413
Minimum	0.250	0.250	0.583	0.405	0.438	0.250	0.583	0.600	0.500	0.250	0.428	0.293	0.475
Maximum	1.000	1.000	1.000	0.923	1.000	1.000	1.000	1.000	1.000	1.000	0.928	0.980	0.888

APPENDIX – C

SPSS output for bivariate correlation

Pearson Correlation Matrix

		IP11	IP12	IP13	IP14	IP15	IP21	IP22	IP23	IP24	IP25	TC	SCS	FLX
IP11	Coeff	1	.162	.086	.475~	.468~	-.215	-.041	.301*	.299*	.321~	.159	-.122	.193
	Sig.		.179	.479	.000	.000	.073	.734	.011	.012	.007	.188	.315	.110
IP12	Coeff	.162	1	.072	.368~	.351~	.649~	.060	-.017	.178	.414~	.382~	.344~	.252*
	Sig.	.179		.555	.002	.003	.000	.619	.886	.142	.000	.001	.004	.035
IP13	Coeff	.086	.072	1	.248*	.420~	.086	.561~	.386~	-.025	.097	.353~	.248*	.438~
	Sig.	.479	.555		.038	.000	.480	.000	.001	.834	.425	.003	.039	.000
IP14	Coeff	.475~	.368~	.248*	1	.669~	.001	.198	.412~	.020	.700~	.525~	.362~	.490~
	Sig.	.000	.002	.038		.000	.996	.101	.000	.872	.000	.000	.002	.000
IP15	Coeff	.468~	.351~	.420~	.669~	1	.085	.347~	.474~	-.011	.380~	.709~	.466~	.584~
	Sig.	.000	.003	.000	.000		.484	.003	.000	.926	.001	.000	.000	.000
IP21	Coeff	-.215	.649~	.086	.001	.085	1	-.017	-.110	.095	.049	.263*	.264*	.095
	Sig.	.073	.000	.480	.996	.484		.889	.364	.434	.686	.028	.027	.436
IP22	Coeff	-.041	.060	.561~	.198	.347~	-.017	1	.417~	-.173	.074	.202	.090	.242*
	Sig.	.734	.619	.000	.101	.003	.889		.000	.152	.542	.094	.457	.044
IP23	Coeff	.301*	-.017	.386~	.412~	.474~	-.110	.417~	1	.167	.243*	.478~	.322~	.484~
	Sig.	.011	.886	.001	.000	.000	.364	.000		.166	.043	.000	.007	.000
IP24	Coeff	.299*	.178	-.025	.020	-.011	.095	-.173	.167	1	-.076	-.074	-.004	.026
	Sig.	.012	.142	.834	.872	.926	.434	.152	.166		.532	.544	.977	.832
IP25	Coeff	.321~	.414~	.097	.700~	.380~	.049	.074	.243*	-.076	1	.400~	.303*	.216
	Sig.	.007	.000	.425	.000	.001	.686	.542	.043	.532		.001	.011	.073
TC	Coeff	.159	.382~	.353~	.525~	.709~	.263*	.202	.478~	-.074	.400~	1	.838~	.746~
	Sig.	.188	.001	.003	.000	.000	.028	.094	.000	.544	.001		.000	.000
SCS	Coeff	-.122	.344~	.248*	.362~	.466~	.264*	.090	.322~	-.004	.303*	.838~	1	.587~
	Sig.	.315	.004	.039	.002	.000	.027	.457	.007	.977	.011	.000		.000
FLX	Coeff	.193	.252*	.438~	.490~	.584~	.095	.242*	.484~	.026	.216	.746~	.587~	1
	Sig.	.110	.035	.000	.000	.000	.436	.044	.000	.832	.073	.000	.000	

~ Correlation is significant at the 0.01 level .

* Correlation is significant at the 0.05 level .

APPENDIX – D

SPSS output of Canonical Correlation:

Run MATRIX procedure:

Correlations for Set-1

	TC	SCS	FLX
TC	1.0000	.8377	.7460
SCS	.8377	1.0000	.5866
FLX	.7460	.5866	1.0000

Correlations for Set-2

	IP11	IP12	IP13	IP15	IP22	IP23	IP25
IP11	1.0000	.1623	.0860	.4680	-.0413	.3006	.3211
IP12	.1623	1.0000	.0717	.3506	.0604	-.0174	.4138
IP13	.0860	.0717	1.0000	.4196	.5608	.3864	.0968
IP15	.4680	.3506	.4196	1.0000	.3473	.4744	.3799
IP22	-.0413	.0604	.5608	.3473	1.0000	.4166	.0742
IP23	.3006	-.0174	.3864	.4744	.4166	1.0000	.2430
IP25	.3211	.4138	.0968	.3799	.0742	.2430	1.0000

Correlations Between Set-1 and Set-2

	IP11	IP12	IP13	IP15	IP22	IP23	IP25
TC	.1594	.3819	.3527	.7089	.2019	.4776	.3996
SCS	-.1219	.3442	.2477	.4661	.0904	.3222	.3029
FLX	.1927	.2524	.4381	.5843	.2416	.4843	.2159

Canonical Correlations

1	.812
2	.536
3	.318

Test that remaining correlations are zero:

	Wilk's	Chi-SQ	DF	Sig.
1	.219	96.570	21.000	.000
2	.641	28.231	12.000	.005
3	.899	6.756	5.000	.239

Standardized Canonical Coefficients for Set-1

	1	2	3
TC	-.976	1.094	-1.693
SCS	.097	-1.725	.637
FLX	-.133	.362	1.460

Raw Canonical Coefficients for Set-1

	1	2	3
TC	-2.020	2.264	-3.505
SCS	.140	-2.493	.920
FLX	-.342	.930	3.757

Standardized Canonical Coefficients for Set-2

	1	2	3
IP11	.341	1.055	-.066
IP12	-.199	-.246	.203
IP13	-.148	.005	.831
IP15	-.793	-.063	-.467
IP22	.278	.445	-.270
IP23	-.374	-.160	.509
IP25	-.121	-.221	-.600

Raw Canonical Coefficients for Set-2

	1	2	3
IP11	.396	1.222	-.076
IP12	-.244	-.301	.249
IP13	-.318	.012	1.783
IP15	-1.524	-.121	-.897
IP22	.611	.977	-.593
IP23	-1.053	-.451	1.431
IP25	-.204	-.373	-1.014

Canonical Loadings for Set-1

	1	2	3
TC	-.994	-.082	-.070
SCS	-.799	-.597	.075
FLX	-.804	.166	.571

Cross Loadings for Set-1

	1	2	3
TC	-.807	-.044	-.022
SCS	-.649	-.320	.024
FLX	-.653	.089	.181

Canonical Loadings for Set-2

	1	2	3
IP11	-.238	.848	-.209
IP12	-.459	-.158	-.185
IP13	-.466	.218	.631
IP15	-.892	.341	-.158
IP22	-.271	.284	.216
IP23	-.615	.265	.326
IP25	-.480	-.014	-.531

Cross Loadings for Set-2

	1	2	3
IP11	-.193	.454	-.066
IP12	-.373	-.085	-.059
IP13	-.378	.117	.200
IP15	-.724	.183	-.050
IP22	-.220	.152	.069
IP23	-.499	.142	.104
IP25	-.389	-.007	-.169

Redundancy Analysis:

Proportion of Variance of Set-1 Explained by Its Own Can. Var.

	Prop Var
CV1-1	.758
CV1-2	.130
CV1-3	.112

Proportion of Variance of Set-1 Explained by Opposite Can.Var.

	Prop Var
CV2-1	.500
CV2-2	.037
CV2-3	.011

Proportion of Variance of Set-2 Explained by Its Own Can. Var.

	Prop Var
CV2-1	.280
CV2-2	.151
CV2-3	.134

Proportion of Variance of Set-2 Explained by Opposite Can. Var.

	Prop Var
CV1-1	.185
CV1-2	.043
CV1-3	.013

------ END MATRIX -----

APPENDIX – E

SPSS output for multiple linear regression analyses (step-wise)

Dependent Variable: TC **Independent Variables**: IP11, IP12, IP13, IP15, IP22, IP23, IP25

Descriptive Statistics

	Mean	Std. Deviation	N
TC	2.9111	.48316	70
IP11	2.8573	.86308	70
IP12	2.1477	.81592	70
IP13	3.6043	.46579	70
IP15	3.3857	.52074	70
IP22	3.6333	.45503	70
IP23	3.1571	.35532	70
IP25	2.4704	.59195	70

Correlations

		TC	IP11	IP12	IP13	IP15	IP22	IP23	IP25
Pearson Correlation	TC	1.000	.159	.382	.353	.709	.202	.478	.400
	IP11	.159	1.000	.162	.086	.468	-.041	.301	.321
	IP12	.382	.162	1.000	.072	.351	.060	-.017	.414
	IP13	.353	.086	.072	1.000	.420	.561	.386	.097
	IP15	.709	.468	.351	.420	1.000	.347	.474	.380
	IP22	.202	-.041	.060	.561	.347	1.000	.417	.074
	IP23	.478	.301	-.017	.386	.474	.417	1.000	.243
	IP25	.400	.321	.414	.097	.380	.074	.243	1.000
Sig. (1-tailed)	TC	.	.094	.001	.001	.000	.047	.000	.000
	IP11	.094	.	.090	.239	.000	.367	.006	.003
	IP12	.001	.090	.	.278	.001	.310	.443	.000
	IP13	.001	.239	.278	.	.000	.000	.000	.213
	IP15	.000	.000	.001	.000	.	.002	.000	.001
	IP22	.047	.367	.310	.000	.002	.	.000	.271
	IP23	.000	.006	.443	.000	.000	.000	.	.021
	IP25	.000	.003	.000	.213	.001	.271	.021	.

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	IP15	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	IP11	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	IP23	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	IP12	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	IP22	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: TC

Model Summary(f)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.709(a)	.503	.495	.34327	
2	.735(b)	.541	.527	.33234	
3	.757(c)	.573	.554	.32267	
4	.780(d)	.608	.584	.31150	
5	.799(e)	.638	.609	.30193	2.233

a Predictors: (Constant), IP15
b Predictors: (Constant), IP15, IP11
c Predictors: (Constant), IP15, IP11, IP23
d Predictors: (Constant), IP15, IP11, IP23, IP12
e Predictors: (Constant), IP15, IP11, IP23, IP12, IP22
f Dependent Variable: TC

ANOVA (f)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.094	1	8.094	68.693	.000(a)
	Residual	8.013	68	.118		
	Total	16.107	69			
2	Regression	8.707	2	4.354	39.418	.000(b)
	Residual	7.400	67	.110		
	Total	16.107	69			
3	Regression	9.236	3	3.079	29.567	.000(c)
	Residual	6.872	66	.104		
	Total	16.107	69			
4	Regression	9.800	4	2.450	25.249	.000(d)
	Residual	6.307	65	.097		
	Total	16.107	69			
5	Regression	10.273	5	2.055	22.538	.000(e)
	Residual	5.834	64	.091		
	Total	16.107	69			

a Predictors: (Constant), IP15
b Predictors: (Constant), IP15, IP11
c Predictors: (Constant), IP15, IP11, IP23
d Predictors: (Constant), IP15, IP11, IP23, IP12
e Predictors: (Constant), IP15, IP11, IP23, IP12, IP22
f Dependent Variable: TC

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.684	.272		2.517	.014		
	IP15	.658	.079	.709	8.288	.000	1.000	1.000
2	(Constant)	.713	.263		2.706	.009		
	IP15	.754	.087	.812	8.668	.000	.781	1.280
	IP11	-.124	.052	-.221	-2.355	.021	.781	1.280
3	(Constant)	.136	.362		.376	.708		
	IP15	.672	.092	.724	7.306	.000	.659	1.519
	IP11	-.135	.051	-.241	-2.641	.010	.773	1.294
	IP23	.281	.125	.207	2.252	.028	.767	1.304
	(Constant)	-.036	.357		-.101	.920		

4	IP15	.585	.096	.631	6.115	.000	.566	1.766
	IP11	-.138	.049	-.246	-2.786	.007	.773	1.294
	IP23	.348	.124	.256	2.814	.006	.729	1.373
	IP12	.121	.050	.205	2.412	.019	.833	1.200
5	(Constant)	.326	.381		.858	.394		
	IP15	.644	.096	.694	6.688	.000	.526	1.903
	IP11	-.171	.050	-.306	-3.414	.001	.707	1.415
	IP23	.445	.127	.327	3.499	.001	.647	1.546
	IP12	.122	.049	.206	2.498	.015	.833	1.200
	IP22	-.213	.094	-.201	-2.278	.026	.729	1.371

a Dependent Variable: TC

Excluded Variables(f)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	IP11	-.221(a)	-2.355	.021	-.277	.781	1.280	.781
	IP12	.152(a)	1.687	.096	.202	.877	1.140	.877
	IP13	.067(a)	.709	.481	.086	.824	1.214	.824
	IP22	-.050(a)	-.550	.584	-.067	.879	1.137	.879
	IP23	.182(a)	1.913	.060	.228	.775	1.290	.775
	IP25	.152(a)	1.668	.100	.200	.856	1.169	.856
2	IP12	.152(b)	1.740	.087	.209	.877	1.140	.704
	IP13	.038(b)	.412	.681	.051	.808	1.237	.636
	IP22	-.108(b)	-1.191	.238	-.145	.826	1.210	.646
	IP23	.207(b)	2.252	.028	.267	.767	1.304	.659
	IP25	.195(b)	2.208	.031	.262	.829	1.206	.722
3	IP12	.205(c)	2.412	.019	.287	.833	1.200	.566
	IP13	-.013(c)	-.144	.886	-.018	.757	1.321	.587
	IP22	-.200(c)	-2.181	.033	-.261	.729	1.371	.604
	IP25	.184(c)	2.134	.037	.256	.826	1.210	.623
4	IP13	-.006(d)	-.064	.949	-.008	.756	1.323	.508
	IP22	-.201(d)	-2.278	.026	-.274	.729	1.371	.526
	IP25	.127(d)	1.402	.166	.173	.724	1.382	.561
5	IP13	.095(e)	.997	.323	.125	.619	1.615	.498
	IP25	.117(e)	1.324	.190	.165	.722	1.386	.520

a Predictors in the Model: (Constant), IP15
b Predictors in the Model: (Constant), IP15, IP11
c Predictors in the Model: (Constant), IP15, IP11, IP23
d Predictors in the Model: (Constant), IP15, IP11, IP23, IP12
e Predictors in the Model: (Constant), IP15, IP11, IP23, IP12, IP22
f Dependent Variable: TC

APPENDIX – F

AHP Weights Matrix: Respondent - Researcher

Criteria	Transforming Capabilities	Modifying Capabilities	Innovating Capabilities	Geometric Mean (GM)	Weights
Transforming Capabilities	1	1	1/5	0.585	0.156
Modifying Capabilities	1	1	1/3	0.693	0.185
Innovating Capabilities	5	3	1	2.466	0.659

Xmax = 3.029; Consistency Index = 0.015; Consistency Ratio = 2.5%

AHP Weights Matrix: Respondent - Technology Manager

Criteria	Transforming Capabilities	Modifying Capabilities	Innovating Capabilities	Geometric Mean (GM)	Weights
Transforming Capabilities	1	1/3	1/5	0.405	0.105
Modifying Capabilities	3	1	1/3	1.000	0.258
Innovating Capabilities	5	3	1	2.466	0.637

Xmax = 3.039; Consistency Index = 0.019; Consistency Ratio = 3.3%

AHP Weights Matrix: Respondent - R & D Manager

Criteria	Transforming Capabilities	Modifying Capabilities	Innovating Capabilities	Geometric Mean (GM)	Weights
Transforming Capabilities	1	1/3	1/5	0.405	0.114
Modifying Capabilities	3	1	1	1.442	0.405
Innovating Capabilities	5	1	1	1.710	0.481

Xmax = 3.029; Consistency Index = 0.015; Consistency Ratio = 2.5%

APPENDIX – G

Position Matrix: Respondent – Researcher

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach	Weight
Transforming Capabilities	0.9	0.5	0.7	0.5	0.156
Modifying Capabilities	0.5	0.3	0.7	0.7	0.185
Innovating Capabilities	0.5	0.3	0.9	0.7	0.659

Position Matrix: Respondent - Technology Manager

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach	Weight
Transforming Capabilities	0.7	0.7	0.5	0.5	0.105
Modifying Capabilities	0.5	0.5	0.7	0.7	0.258
Innovating Capabilities	0.3	0.7	0.7	0.9	0.637

Position Matrix: Respondent - R & D Manager

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach	Weight
Transforming Capabilities	0.7	0.5	0.7	0.7	0.114
Modifying Capabilities	0.5	0.3	0.7	0.5	0.405
Innovating Capabilities	0.3	0.5	0.7	0.7	0.481

APPENDIX – H

Weighted Position Matrix: Respondent – Researcher

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1406	0.0781	0.1093	0.0781
Modifying Capabilities	0.0926	0.0556	0.1296	0.1296
Innovating Capabilities	0.3293	0.1976	0.5928	0.4611

Weighted Position Matrix: Respondent - Technology Manager

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.0733	0.0733	0.0524	0.0524
Modifying Capabilities	0.1291	0.1291	0.1808	0.1808
Innovating Capabilities	0.1911	0.4459	0.4459	0.5733

Weighted Position Matrix: Respondent - R & D Manager

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.0798	0.0570	0.0798	0.0798
Modifying Capabilities	0.2027	0.1216	0.2838	0.2027
Innovating Capabilities	0.1442	0.2403	0.3364	0.3364

APPENDIX – J

Weighted Position Matrix - 80% Optimism

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1271	0.0739	0.0979	0.0743
Modifying Capabilities	0.1807	0.1144	0.2529	0.1881
Innovating Capabilities	0.2923	0.3962	0.5415	0.5259

Weighted Position Matrix - 60% Optimism

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1137	0.0696	0.0865	0.0688
Modifying Capabilities	0.1587	0.0997	0.2221	0.1735
Innovating Capabilities	0.2553	0.3466	0.4902	0.4786

Weighted Position Matrix - 40% Optimism

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1002	0.0654	0.0751	0.0633
Modifying Capabilities	0.1366	0.0850	0.1913	0.1589
Innovating Capabilities	0.2182	0.2969	0.4390	0.4312

Weighted Position Matrix - 20% Optimism

Profile ⇨ Objectives ⇩	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Transforming Capabilities	0.1002	0.0654	0.0751	0.0633
Modifying Capabilities	0.1366	0.0850	0.1913	0.1589
Innovating Capabilities	0.2182	0.2969	0.4390	0.4312

APPENDIX – K

Dominance Matrix: Hadley's 80% Optimism

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	3	3
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	0	3	--
Column Sum	4	1	8	5
Rank	**3**	**4**	**1**	**2**

Dominance Matrix: Hadley's 60% Optimism

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	3	2
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	1	3	--
Column Sum	4	2	8	4
Rank	**2**	**4**	**1**	**2**

Dominance Matrix: Hadley's 40% Optimism

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	3	2
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	1	3	--
Column Sum	4	2	8	4
Rank	2	4	1	2

Dominance Matrix: Hadley's 20% Optimism

⇩ Profiles ⇨	Hard technology adoption approach	Soft technology adoption approach	Technology Adaptation approach	System Adaptation approach
Hard technology adoption approach	--	1	2	2
Soft technology adoption approach	2	--	3	2
Technology Adaptation approach	1	0	--	0
System Adaptation approach	1	1	3	--
Column Sum	4	2	8	4
Rank	2	4	1	2