EVALUATING THE ROLE OF INVESTMENT, PRODUCTION AND LINKAGE CAPABILITY IN IMPROVING THE PERFORMANCE OF MSMEs

A thesis report submitted in partial fulfillment of
the requirement for the award of the degree of

MASTER OF ENGINEERING
(PRODUCTION AND INDUSTRIAL ENGINEERING)

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DECLERATION

I, **Navdeep Singh** hereby declare that the work which is being presented in this thesis report entitled, **'Evaluating the Role of Investment, Production and Linkage Capability in Improving the Performance of MSMEs'** by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Production and Industrial Engineering from MED, Thapar University, Patiala is an authentic record of my own work carried under the supervision of Dr. Tarun Nanda, Assistant Professor, Mechanical Engineering Department, Thapar University, Patiala.

The matter presented in this report has not been submitted in any other University/Institute for the award of Master of Engineering or any other degree.

Navdeep

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Date 18/07/2012

This is certified that the above statement made by the candidate is correct to best of my knowledge.

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CERTIFICATE

This is to certify that the thesis report entitled, '**Evaluating the Role of Investment, Production and Linkage Capability in Improving the Performance of MSMEs**', submitted by Navdeep Singh (Regd. No. 801082022), in partial fulfillment of the requirement for the award of Master of Engineering in Production and Industrial Engineering from MED, Thapar University, Patiala, is a record of candidate's own work carried out by him under my supervision. The matter embodied in this thesis report is original and has not been submitted for the award of any other degree.

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CONTENTS

ABSTRACT

Technology is recognized as one of the most valuable resources that provide sustainable competitive advantages. Technical advancement is a key driving force and an important source of economic and social development. In addition, technology has become the center of competition in the world market. The diffusion, assimilation and further improvement of new technology determine the patterns of competition, growth and trade around the world at large. The capability of accessing new technology thus affects the ability of companies in emerging countries to build indigenous technological capabilities and compete in world markets. Accordingly, technological capability (TC) has become the focus of attention not only among academicians, but also among entrepreneurs of manufacturing organizations.

Industrial development is recognized as a process of acquiring technological capabilities and transforming them into product and process innovations in the course of continuous technological change. In other words, the process of industrial development, in fact, is the process of generating technological capabilities. Therefore, technological capabilities play a strategic role in affecting the competitive advantage of a company, an industry, and even a country. Technological capability has become a pervasive factor of production in the future. Thus, the development of technological capabilities is critical for companies, especially those manufacturing companies in the countries which are in a catch-up phase of industrialization.

The objective of the present work is to analyze the technology innovation capabilities of small scale manufacturing industry especially the cutting tool and machine tool industry in the state of Punjab. The issues explored include, present status and future scope of technology innovation capabilities of small scale manufacturing industry regarding investment capability, production capability and linkage capability, reasons for low performance in the area of firm performance include innovation performance, sales performance and product performance etc.

The present report is subdivided into five main chapters. The first chapter gives introduction about SMEs, technology capability and the need for enhancing technology capability of the organizations. The second chapter brings together the extensive literature regarding the various factors influencing the technology capability of the organizations and the various gaps in the present literature. Third chapter puts forward the methodology to be adopted for carrying out the future research, fourth chapter presents the findings of survey based results, the results obtained

after quantitative analysis of survey data. Analysis of three input variables viz. investment capability, production capability and linkage capability with respect to output variables viz. innovation performance, sales performance and product performance has been performed using correlation and regression analysis. Principal component analysis has been done to reduce the issues under each input factor. Last and final chapter presents the conclusion work and also the scope of future work.

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CHAPTER - I

INTRODUCTION

1.1 General

More and more companies find that only with good quality, a sufficiently high efficiency, and flexible organizational structure cannot meet the requirements to remain competitive. They will have to pay more attention to the effective management of technological innovation. Technological innovation management is for the allocation of resources in technological innovation process, including technical origin R&D, technology (including designing, manufacturing, sales and service of commercial, industrial processes) and other processes (Liao *et al.*, 2011).

Innovations are currently a fundamental prerequisite of competitiveness (Striss *et al.*, 2009). The economic crisis forced most businesses to savings in all business areas. Successful companies will be the ones that will have implemented an innovative strategy, will invest in research, development and innovate. Innovation is regarded as a key business process; it means that companies are trying through them to achieve a competitive advantage. The basic precondition for the creation and use of innovation in the enterprise is a well formulated and implemented innovation strategy (Lendel *et al.*, 2011).

Today, almost all organizations face a dynamic environment characterized by rapid technological change, shortening product life cycles, and globalization. Organizations, especially technologically- driven ones, need to be more creative and innovative than before to survive, to compete, to grow, and to lead (Tierney *et al.*, 1999).

Despite the pressure to promote innovation, few companies have gotten to systematize the process of innovation, making it feasible and, most important, replicable. An innovation process depends on many aspects and needs an adequate environment to happen. Among these aspects, organization’s cultural knowledge, which governs the way in which the company operates and how its collaborators interact with each other are important. Thus, a key challenge to support the generation of innovation is to understand how the innovation process happens within the organizations. However, this is not an easy task, since the innovation process is usually adhoc, complex, people-dependant and influenced by the environment (Escalfoni *et al.,* 2011).

1.2 Need of Innovation

The most frequently mentioned synthesis of definitions of innovation is the one cited by OECD (1981) where innovation 'consists of all those scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured products, the commercial use of new or improved processes or equipment or an introduction of a new approach to a social service. R&D is only one of these steps'. Innovation may be 'radical', i.e. innovation involving new developments within a sector or economy, 'adaptive', i.e. innovation concerning new changes to an individual firm but which other firms may have already adopted, or 'incremental', i.e. innovation involving modifications of existing products and services (Tsekouras *et al.,* 2008).

A common theme in many industrialized countries has been the recognition of contributions of small and medium sized enterprises (SMEs) to the performance of local and national economies, both in terms of creating new jobs and stimulating the competitiveness of their economies. Innovation is particularly important if traditional industries in industrialized countries are to compete with industries in emerging nations which have significant low-cost production advantages (Devins, 2007). This has led to the need for industrialized economies to develop high value-added processes to retain their competitive advantage. However, with a few notable exceptions (Oakey et al, 1988; Rothwell, 1993), there is a lack of research in relation to the key value-adding process of R&D in the SME context.

Organizations have been focusing on innovation as a way to improve the quality of products and services, pointing to new practices and business opportunities. Innovation is certainly an important enabler of competitive advantage (Drucker, 2006).

Innovation in the manufacturing sector generally focuses on process improvements, for which formal structures and systems are necessary to squeeze costs out, and large manufacturing firms have generally succeeded with this strategy by focusing on process improvement (Wheelen and Hunger, 1999; Bessant and Tidd, 2007).

The world has re-discovered India and the Indian economy in the recent past. The Indian economy is on a growth trajectory and one after another studies are projecting India as among the leading economies of the future. The role and significance of India in the global economy is continuously increasing. With a billion plus population and rising incomes, India offers enormous opportunities to both individuals and organizations. There is growing interest on exploring India among both researchers and practitioners. Innovation has again gained popularity in the recent past among both researchers and practitioners. Concepts like disruptive innovations and blue ocean strategy have already gained popularity. There is a need for greater interaction, sharing, coordination and learning from each other in an organization spread across many countries (Molina and Pietrobelli, 2012).

1.2.1 Innovation in MSMEs

Nowadays, majority of the MSMEs in almost all industries face growing competition due to internationalization. Some of the principal drivers for the growing internationalization are rooted in political and economic evolutions, such as liberalization and globalisation, and technological innovations. Even primarily domestically oriented SMEs must operate internationally in order to guarantee their competitiveness and viability. During the most recent years, SMEs have taken up an increasingly active international role. Evidence supports the idea that foreign market entry, regardless of mode, significantly increases firm development, performance and profitability, and thus home country's economic wealth. SME development fosters employment, economic growth and technological advances. Not surprisingly, small firm development has become a central goal in economic policies (Maeseneire and Claeys, 2012).

It is not statistically evident that larger firms are better than SMEs in new-to-the-world type innovation, meaning that SMEs may well have capacity for innovation, especially radical innovation. It is agreed that, while SMEs' flexibility and specificity can be advantages in accelerating innovation, few of them have sufficient capacity to manage the whole innovation process by themselves, and this encourages them to collaborate with other firms (Edwards *et al.*, 2005).

SMEs can lack the resources and capabilities in manufacturing, distribution, marketing and extended R&D funding, which are essential for transforming inventions into products or processes. As a result, while many studies have shown that SMEs tend to have a higher R&D productivity than larger firms (although there is considerable variation by industry, there is still much debate on assessing the innovativeness of SMEs because of their material or resource factor disadvantages (Yoon *et al.*, 2010).

Innovation has long been considered as the key factor for the survival, growth and development of small and medium-sized enterprises (SMEs). For these organizations, a greater innovation capacity is deemed to counterbalance their greater vulnerability in a globalized business environment and in an economy that is now knowledge based. As SMEs must continually seize new opportunities in order to sustain a competitive advantage, their capacity to develop new products and to innovate 'are in the very core of value creation'. And manufacturing SMEs in particular must continuously improve their manufacturing processes in order to ensure long-term sustainability (Raymond and St-Pierre, 2010).

Encouraging innovation in small enterprises has been at the heart of policy incentives owing to the important role that small enterprises play in economic development. Despite their important role, innovation in small and micro enterprises has received only scant attention, while the majority of studies have focused on innovation in large and medium-sized enterprises (Forsman, 2011).

Although the research on innovation tends to focus primarily on large firms, innovation is at least as important for small firms. The strategic position of a small company depends on its ability to offer high-quality products and services that fit the needs of the market. Therefore, a permanent flow of product innovations is significantly important to small firms (Simon *et al.,* 2000).

Innovation in small firms differs considerably from innovation in large firms (Rothwell, 1991; Rothwell and Dodgson, 1994; Hadjimanolis, 2000). Small firms react more quickly to changing market requirements than large firms. Their size makes them more internally flexible because they are free of the bureaucratic inertial forces that plague larger firms. Behavioural advantages, such as internal flexibility and responsiveness, are the main keys to success for small firms that engage in innovative activities. Large firms generally enjoy resource advantages (Rothwell and Dodgson, 1994), but suffer from being notoriously slow to react to changes in their environment. For many small firms, new product development tends to be a haphazard process: it simply 'happens'. In these small firms, the innovation process is mostly *adhoc*; not the output of a formal, structured process. This applies to service and low-tech manufacturing firms in particular (Acs and Audretsch, 1990).

1.3 MSMEs in India

Small and medium-size enterprises (SMEs) are considered as one of the important factors to work an economic miracle in many countries and regions. According to established practice in the world, the strength of an economic power lies not only in the success of large enterprises, but also in SMEs. SMEs contribute a lot to the country's modernization drive (Qinglana and Yingbiao, 2011).

Table 1.1 Contributions of MSMEs in the GDP

Year	**Contributions of SMEs (%) at 1999-2009 prices in Gross Domestic Product (GDP)**
1999-2000	5.86
2000-2001	6.04
2001-2002	5.77
2002-2003	5.91
2003-2004	5.79
2004-2005	5.84
2005-2006	5.83
2006-2007	7.20
2007-2008	8.00
2008-2009	8.72
Note: The data for the period upto 2005-2006 is for small scale industries (SSI)	

Source- Annual Report (2010-2011), Ministry of Micro, Small and Medium Enterprises, GOI.

Worldwide, the Micro, Small and Medium Enterprises (MSMEs) have been accepted as the engine of economic growth and for promoting equitable development. The major advantage of the sector is its employment potential at low capital cost. The labour intensity of this sector is much higher than that of the large enterprises. It is a nursery of entrepreneurship, often driven by individual creativity and innovation (MSMED Policy Note, 2011). In India, MSMEs play a pivotal role in the overall industrial economy of the country. These contribute 8 per cent of the country's Gross Domestic Product, 45 per cent of the manufactured output and 40 per cent of its exports. MSMEs provide employment to about 60 million persons through 26 million enterprises. In recent years, this sector has consistently registered higher growth rate compared to the overall industrial sector. With its agility and dynamism, the sector has shown admirable innovativeness and adaptability to survive the recent economic downturn and recession. Thus, MSMEs are important for the national objectives of growth with equity and inclusion. Tamil Nadu accounts for the largest number of (15.07%) MSMEs in the country with 6.89 lakhs registered MSMEs, producing over 8,000 varieties of products for a total investment of more than Rs.32,008 crores (MSMED Policy Note 2011).

Despite their commendable contribution to the nation's economy, SME sector does not get the required support from the concerned government departments, banks, financial institutions and corporate, which is a handicap in becoming more competitive in the national and international markets. MSMEs face a number of problems - absence of adequate and timely banking finance, limited capital and knowledge, non-availability of suitable technology, low production capacity, ineffective marketing strategy, identification of new markets, constraints on modernisation & expansions, non availability of highly skilled labour at affordable cost, follow up with various government agencies to resolve problems etc (SMEs Chamber of India, 2010).

Table 1.2 Distributions by Nature of Activity

Distributions by Nature of Activity	Number of units in lakh
Manufacturing/ Assembling/ Processing	10.49 (67.10%)
Services	2.62 (16.78%)
Repairing & Maintenance	2.52 (16.13%)
Total	15.64 (100%)

Further 90.08 % of the enterprises in the registered MSME sector are proprietary concerns. About 4.01 % of the enterprises are run by partnerships and 2.78 % of the enterprises are run by private companies. The rest are owned by public limited companies, cooperatives/trusts or others (Annual Report MSME, 2010).

Table 1.3 Distributions by Type of Organization

Distributions by Type of Organization	Number of units in lakh
Proprietary	14.09 (90.08%)
Partnership	0.63 (4.01%)
Private Company	0.43 (2.78%)
Public Limited Company	0.08 (0.54%)
Cooperatives	0.05 (0.30%)
Others	0.36 (2.30%)

1.4 Industrial Scenario

The uncertainties due to globalization of the Indian market after economic reforms have led to drastic changes in the approach of manufacturing organizations for developing various competencies to get competitive advantage. The new competition is in terms of reduced cost, improved quality, products with higher performance, a wider range of products with better service, all delivered simultaneously (Nanda and Singh, 2009).

According to the Global Innovation Index, 2011, published by INSEAD, (Fontainebleau in France), India's overall rank in Global Innovation Index is 62 out of 125 participating nations. India's position, however, is dragged down its performance on the innovation input (Innovation input has five enabler pillars: institutions, human capital and research, infrastructure, market sophistication and business sophistication) ranked 87th out of 125 participating nations. India is in last quintile on institution's sub-pillar business environment (111th); human capital and research's sub-pillar elementary education (115th) and business sophistication's sub-pillar knowledge worker (104th). But the country has high marks with in top 40 on the human capital and research's sub-pillar R&D (ranked 35th) and infrastructure's sub-pillar general infrastructure (ranked 11th). R&D activities that lead to breakthrough are gaining momentum in the country. The manufacturing sectors in the country have started using intellectual property as strategical tool to innovate and gain competitiveness. The following table shows the increased use of patents by Indian industry:

Table 1.4 Use of Patents by Indian Manufacturing Sector

Year	*No. of Patent Application Filed*	*No. of Patent Granted*
2004-05	17000	2000
2008-09	36000	16000

Source: Annual Report MSME, 2010

Over the last few years, the number and quality of incubators, early stage funders and venture capitalists have grown. This has helped ideators and inventors present proof of concept and secure initial funding. The country ranks 52 on research collaboration between the universities and industry. This type of industry-institute interaction lacks in India with a low, 52nd ranking. (Global Innovation Index Report, 2011).

The status of Indian manufacturing industry in various areas which affect innovation capabilities is presented in Table 1.5.

Table 1.5 Innovation Capability of Indian Industry

S.No.	Parameter	India's Rank (125 countries)
1	Gross expenditure on R&D	38
2	Quality research institutions	29
3	Electricity Output	92
4	Quality of trade and transport	46
5	Domestic credit to private sector	50
6	Firms offering formal training	85
7	R&D performed by business	50
8	R&D financed by business	47
9	University- industry collaboration	52
10	State of cluster development	31
11	Intensity local competition	27

Source: Global Innovation Index Report, 2011

1.5 Research Problem

The development of technology capabilities enables the innovative organization to successfully develop and implement strategies for innovation, seeking to build lasting competitive advantages. This allows the organization, if not necessarily to achieve ways to guarantee success, positively respond to market challenges with greater accuracy and flexibility. Technological innovation capabilities consist of a particular set of organizational and dynamic capabilities that critically contribute to the achievement of objectives of technological innovation. Nonetheless, it is necessary to clarify that this is a complex, elusive and full of uncertainty concept, which is difficult to determine and whose measurement requires to simultaneously consider multiple quantitative and qualitative criteria applied to the organization. Despite the complexity of technological innovation capabilities, their measurement and evaluation are essential. The present research work has been carried out for the small scale sector in the region. It aims to investigate the nature of technological innovation capabilities in the small scale sector by identifying the key inputs and outputs of a strategic development program, determining their status in the industrial sector and determining the key input parameters which make a significant contribution to performance improvements.

1.6 Organization of the Thesis

The write up of the thesis is divided into six chapters as discussed as follows. The overall structure of thesis is presented in Figure 1.1.

Chapter I justifies the need of the present work. It underlines the aim of the research problem and covers the organization of thesis.

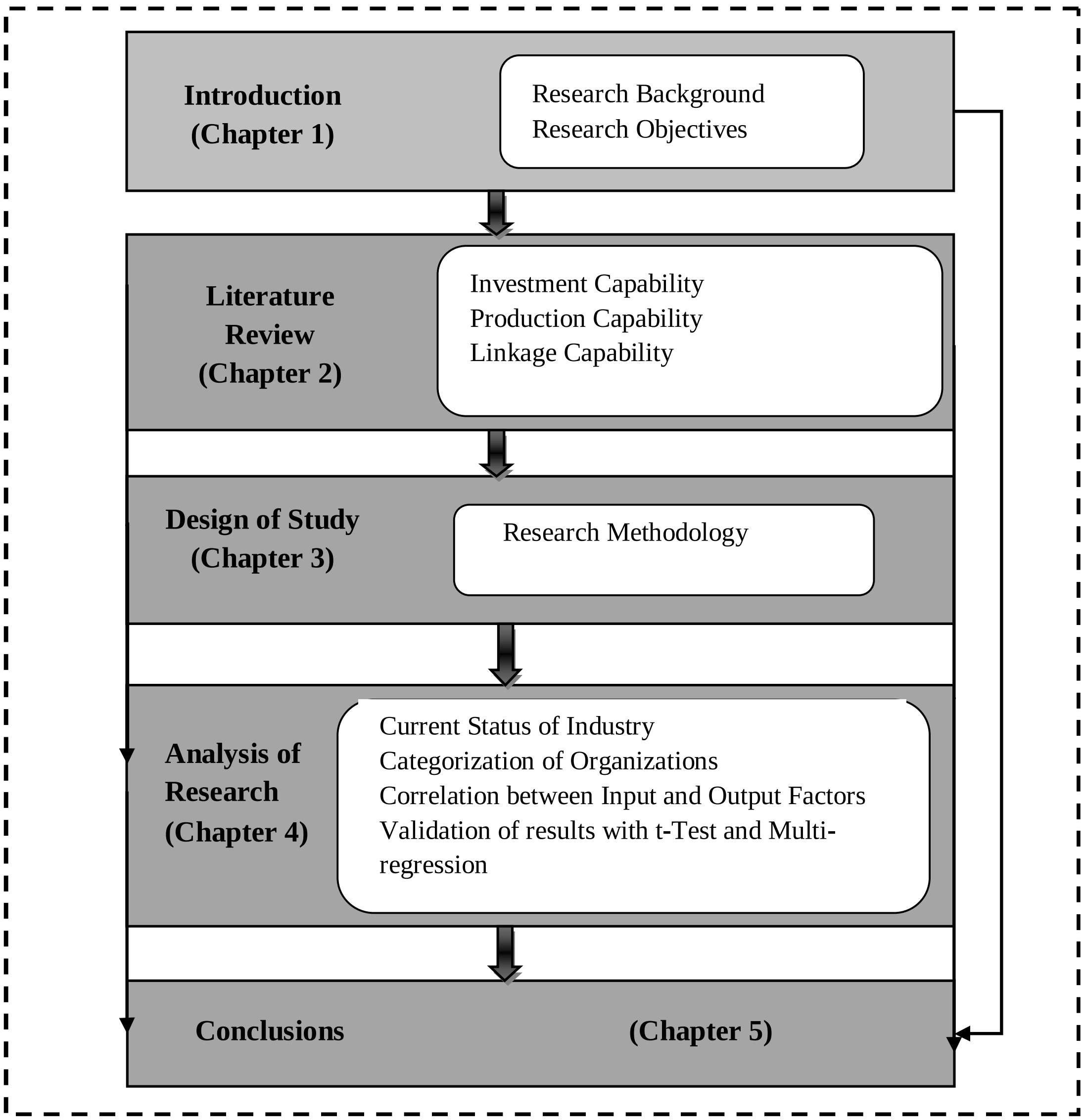

Figure 1.1 Thesis Structure

Chapter II reviews in detail the previous studies in the field to identify the factors which facilitate technological improvements in manufacturing enterprises. It identifies the key inputs and outputs issues affecting the research problem. The chapter identifies the main limitations in the existing academic writings.

Chapter III introduces overall design of the study. It explains the methodology adopted for carrying out the research work. The details of work done in each phase of research, the tools and techniques used have been presented.

Chapter IV presents the results of detailed survey conducted in various manufacturing enterprises. Descriptive and empirical analysis of data has been carried out to assess the status of present level of different dimensions of the research problem.

Chapter V presents a synthesis of learning issues and outcomes of survey and their utilization through a qualitative model to evolve a strategic development program for small scale industry.

Chapter VI covers the summary of research work, its results, conclusions, and the recommendations. The limitations along with scope for future work have also been covered in subsequent sections of this chapter.

1.7 Concluding Remarks

An organized attempt has been made to make this study exhaustive, intensive and broad based as possible, for investigating the role of innovation and other development initiatives in technology innovation in small and medium enterprise.

Globalisation has changed the competitive environment for the manufacturing sector drastically. To be successful, companies have to compete not only against domestic competitors but also against the best companies in the world. In order to compete effectively companies must embrace new technologies and innovation.

Presently the Indian manufacturing industry is very small by global standards and heavily depends on foreign sources of technology. The over dependence of the Indian firms on external technology acquisition have rendered their available technologies and skills inefficient and out-dated. They should start managing innovation in research and development activities to develop cutting edge technologies and products.

CHAPTER - II
LITERATURE REVIEW

2.1 Introduction

This chapter is an attempt to record in brief what has been reported in research literature on various aspects of technology capability initiatives required to become competitive. The literature reported has been organized into the following broad headings:

- Need of technology capability
- Technology capability defined
- Key elements of technology capability
- Technological capability in MSMEs
- Assessment of technology capability

2.2 Need of Technology Capability

Technologies are changing so rapidly and across so broad a front that some analysts see the emergence of a new industrial revolution, driven by a new technological ‘paradigm’. This paradigm involves not only new technologies and skills in the traditional sense, but also different work methods, management techniques and organizational relations within firms. It implies new linkages and information flows between enterprises and between the productive sectors and academic disciplines. As technology and capital move more rapidly and freely across national boundaries, and new transport and communications technologies shrink economic space, it also entails a significant reordering of comparative advantage between countries. While the main locus of technical progress is the advanced industrial world, developing countries are just as affected, since no productive activity, even in traditional sectors, is insulated from the technological revolution (Freeman and Perez, 1988).

The main agent for technological activity is the individual firm, which learns to use new technologies, adapt them, improve upon them and create new knowledge. The firm exists in a world in which information is imperfect and ‘fuzzy’, the future risky and uncertain, factor markets imperfect and a significant part of technology is tacit (requiring considerable efforts on the part of the recipient to learn). Under these conditions, each enterprise has its own learning trajectory, depending upon how it perceives its environment, engages in the technological process and creates the 'routines' to cope with the lack of perfect knowledge (Nelson and Winter, 1982). The learning process is unpredictable, path-dependent and incremental, differing by firm, industry and circumstance (Lall, 1992).

2.3 Technology Capability

The definition of technological capability varies in perspective, depending on the aims of the researchers. Lall (1990) defines technological capability (TC) broadly as 'the entire complex of human skills (entrepreneurial, managerial and technical) needed to set up and operate industries efficiently over time'. He defines TC in a narrow sense as the capability to execute all the technical functions entailed in operating, improving and modernizing the company's production facilities. Westphal *et al.*, (1985) and Kim (1997) define the term 'technological capability' from the aspect of corporate development. Technological capability 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 a changing economic environment (Westphal *et al.*, 1985; Kim, 1997).

Pack and Westphal (1986) place technological capability squarely at the centre of industrial development: to them, industrial development *is* a process of acquiring technological capability in the course of technological change and the costs of achieving international competitiveness are the costs of acquiring technological capability. Even though capability development is uncertain and costly, it is required to increase productivity and engage in cumulative processes of capability acquisition and industrialization.

Technological capability is defined as the knowledge and skills required for firms to choose, install, operate, maintain, adapt, improve and develop technologies. The basic point of departure of this literature is that the existence of such capability cannot be taken for granted. It has to be acquired, necessitating purposive efforts aimed at assimilating, adapting and modifying existing technologies and/or developing new technologies (Adler *et al.*, 1991).

Technological capability may be subdivided into three main subcapabilities. Lall (1992) distinguishes by function between *investment*, *production* and *linkage capability*.

Investment: Project execution including feasibility studies, technology and equipment search, assessment of suppliers, training for start- up and involvement in detailed engineering.

Production: This is subdivided into process and product technology. Process technology includes quality management, maintenance, plant layout, inventory control and improvements in equipment and processes. Product technology includes mastering product design and specification, improving existing products, developing new products and licensing product technology. Quality management include management leadership, human resource management, process management, customer focus, quality planning, quality structure and use of quality tools on shop floor.

Linkages: These include linkages with suppliers, subcontractors, and institutions that provide technical, training and other forms of assistance.

The information and skills (technical, organisational and institutional) that allow productive enterprises to utilise equipment and information efficiently are defined as technological capabilities. Such capabilities are firm-specific, a form of institutional knowledge that are made up of the combined skills and experience of its members (Lall 1995).

Much effort among scholars and practitioners alike has been devoted to understanding the economic significance of technology and technological development. The fundamental role of technology in economic development was quantified by work within growth accounting from the 1950s onwards. Somewhat surprisingly, calculations showed that not just a large part but the majority of the economic growth had to be attributed to an exogenous 'technical change' rather than to growth in the conventional factors of production (Gammeltoft, 2010).

TICs are defined as comprehensive set of firm characteristics that facilitate and support the firm's technological innovation strategies (Yam *et al.*, 2010).

Technology capability underlies the successful technology development of innovative firms. Infact, capabilities may support a sequence of products or multiple products simultaneously. Capabilities refer to the ability of an organization to perform a coordinated set of task, utilizing organizational resources for the purpose for achieving a particular end result; and organizational resources refer to an asset or input to production that an organization owns, controls or has access to on a semi permanent basis. Capabilities develop as a result of recombining and/or integrating knowledge with in the firm. Thus, capabilities are developed through a process that involves the interpretation of past individual and organizational experience as a basis for present and future action, referred to as the firm's 'combinative capabilities' or 'architectural competence' (Banerjee, 2012).

2.3.1 Investment Capabilities

Investment Capabilities are the skills, knowledge etc. needed to identify, prepare and obtain technology to design, construct and equip an expansion or a new facility. They include capital costs of the project, the selected technology and equipment and the understanding gained by the operating firm of the basic technology involved (Lall, 1987, 1992; Domene and Pietrobelli, 2012). Investment capabilities have two elements: pre-investment and project execution. Under each element there are sub-elements to measure those ranging from routine to innovative activities. The spending that a firm makes in different innovation activities (e.g. in-house R&D, purchasing license and patents etc.) shows its commitment to the accumulation of knowledge that will give rise to new products/process or other kinds of innovation. Investment capabilities are the skills to identify needs, prepare and obtain the necessary technology, then design, construct, equip, and staff the facility, before a new facility is commissioned or existing plant is expanded (Salomon *et al.,* 1994).

The positive relation between firm's investment in technological innovation and firm performance has been supported by various arguments: it enables firm to achieve greater capability to meet the demands of its changing domestic and international market (Zahra and George, 2002), thus give firm a good performance. It also enables firm to exploit the intangible technological assets, which can be beneficial to the learning process (Xie, 2004).

2.3.2 Production Capabilities

Production capabilities start from the last step of the first typology: basic technology skills, like quality control, operation, and maintenance to more advanced ones like adaptation or improvement to research, design, and innovation. This implies in some way technology mastery and in others, minor or major innovation (Lall, 1987; Domene and Pietrobelli, 2012).

Production Capabilities influence the productivity of labor and capital as well as efficiency in material and energy used. They have three elements: process engineering, product engineering and industrial engineering. Process engineering includes necessary activities for production. Product engineering contains activities required to produce products or improve product specifications, such as assimilation of product design, improvement in product quality, and basic research. Industrial engineering involves monitoring and control functions for process and product engineering. So technological production capabilities include all the skills related to the handling of these three engineering-process, product and industrial, along with supervision functions associated with production process (Lall, 1992). These production capabilities, together with R&D, are essential to the firm's technology development (Bell and Pavitt, 1993).

Production capabilities range from basic skills like operation and maintenance to more advanced ones like adaptation or improvement (Moreau, 2011).

2.3.3 Linkage Capabilities

Linkages capabilities are the skills, knowledge and organization needed to transmit information, skills, and technology to receive knowledge from component or raw material suppliers, consultants, service firms, and technology institutions. Consequently, they affect not only the firm but the whole industrial structure. They also include the access to external technical information and support (from foreign technology sources, local firms and consultants, and the technology infrastructure of laboratories, testing facilities, standards institutions and so on); and access to appropriate 'embodied' technology in the form of capital goods from the best available sources, domestic or foreign (Lall, 1987; Domene and Pietrobelli, 2012).

Innovation cannot be regarded purely as an internal matter as firm's external linkages or networks may also play a potentially important role (Bougrain and Haudeville, 2002). Also, the external linkages may help by stimulating creativity, reducing risk, accelerating or upgrading the quality of the innovations made, and signaling the quality of firm's innovation activities. Linkages within the economy involve abilities to organize procurement of goods and services, knowledge and technology transfer with suppliers and S&T links with research institutes, universities and other organizations. Firm's technological linkages capabilities can be defined here as the ability to transmit information, skills and technology, and to receive them from other departments of the company, clients, suppliers, consultants, technological institutions and so on (Powell, 1998).

Linkage capabilities include establishing links among other enterprises, suppliers, sub-contractors and services firms, as well as with institutions such as universities, consultants, or development agencies: and therefore foster the diffusion of technology within the firm, and throughout the economy (Moreau, 2011).

Table 2.1 Classification of Linkage Capabilities (Jagersma, 2008)

Type	Capability	Definition
Learning-by doing, Simple formal R&D Research-Based	Local Procurement of goods and services.	This covers all activities that involve buying, contracting, purchasing, sourcing or tendering within local environment.
	Information exchange with Suppliers	Hand over and receive information about processes and products with suppliers and customers.
	Cooperative R&D	Research and development – all activities related to the evolution of new products and services inclined to work together with another or others for a common purpose.
	Licensing own Technology to others	Business arrangement in which the manufacturer grants permission of a product to manufacture that product (or make use of that proprietary material) in return for specified royalties or other payment.
Import of technology, Search Based	Coordinated design	Inclined to work together with another or others for a product or system design that can be plugged in, turned on, and operated with little or no additional configuring due cooperation with each other.

Small and medium enterprises (SMEs) play a predominant role in most developed and developing economies not only because of their number and variety but also due to their involvement in all segments of the economy. But SMEs, especially in developing countries, have been exposed to intense competition due to the accelerated process of globalization, which brings out the need for SMEs to develop competitiveness for their survival as well as growth. SMEs, in general, are constrained in terms of resources such as technology, finance, marketing and human resources. The ability of SMEs to compete in the global market depends on their access to these resources and those SMEs that have better access to these resources are able to exhibit better innovative and economic performance. External Linkages with large enterprises (LEs) provides SMEs better scope for accessing these resources (Kumar and Bala Subrahmanya, 2010).

In order to foster their innovativeness, businesses increasingly engage in cooperative agreements with a wide range of partners to access external resources. These partnerships are developed to create value by externally accessing and leveraging strategically critical resources to support the firm's innovation process. A considerable share of innovating firms establishes strategic R&D links with suppliers, customers, competitors, and universities simultaneously. Companies collaborating with customers primarily search for new ideas or ways to reduce uncertainty associated with market introduction of innovations. In contrast, partnerships with suppliers generally aim at input quality improvements or cost reductions from process innovations (Classen *et al.*, 2012).

The important issues under this key area are discussed as follows:

Table 2.2 Description of Linkage Capability's components

Factors	*Description*	*Supporting Literature*
Inter-firm Linkages and Subcontracting	• Inter-firm linkages involve all possible forms of economic relationships between firms to gain competitive and cooperative advantages. Inter-firm linkages can take several forms: backward, forward or horizontal. Backward linkages exist when large firms acquire goods or services from smaller firms and forward linkages occur when one firm sells goods or services to another firm mainly for distribution. Horizontal linkages involve interactions with firms of the same industry for joint ventures • Subcontracting relationship of SMEs with LEs is an important source for transfer of technologies, leading to innovative performance of SMEs. The international expansion of trans-national corporations (TNCs) to developing countries in the globalisation era provides increasing opportunity of subcontracting relationships for local SMEs and an important source of technology resulting from the linkages that SMEs can forge with TNCs. • Comparison of the innovation-related characteristics of large firms with those of small firms reveals that in many cases an innovative disadvantage of large firms is an innovative advantage for small firms, and vice versa, which can make collaboration between firms of two different sizes desirable for both parties. Thus alliance between small and large firms, which characteristically possess complementary resources, can facilitate innovation success. • From an operational perspective, there are many forms of collaboration, ranging from one-to-one alliances through to multi-firm industrial clusters. Whilst the nature of alliances may differ, they all have to confront a number of common issues such as: *integration, organizational barriers, trust, and ongoing learning*.	*Rothwell, 1991; Hyland and Beckett, 2005; Kumar and Bala Subrhmanya, 2010*
Collaboration between Industry and Academia	• Industry–University (I-U) alliances represent an evolving trend for the advancement of knowledge and new technologies. Collaboration between industries and universities has emerged as one of the priorities in the OECD countries and has become a trend in European innovation policy. Relationships of this type have long been considered crucial to the development of the innovation system in any country. • The collaboration of university and industry leads to mainly two types of transfers from university to industry, these are R&D results transfer and technology transfer. The R&D results transferred leads to innovative ideas in industry which leads to new product development with the help of technology transfer from university to industries. For firms, U–I collaborations provide access to new knowledge and technologies, can solve technological problems in products and manufacturing processes, and maintain access to highly trained students, facilities and faculty members in university. • Industry-University research strategic alliance is a new pattern to convert economic growth methods as well as to implement the scientific outlook on development. Among partners external to the firm, collaboration with universities has been championed as a vital component of innovation in knowledge-intensive sectors within regions. Industry-University collaboration can stimulate learning and help drive the advancement of new technologies.	*OECD, 1997; Cohen et al., 1998; Rasmussen et al., 2006; D'Este and Patel, 2007; Feng et al., 2011,*

Firms, in general, should develop innovative capabilities for their survival and growth in the era of global competition. Firms rely either on their internal technological capabilities and/or their external linkages as the sources of innovation. With the pace of technology development, access to knowledge and resources from outside the firm is becoming increasingly important (Edwards and Delbridge, 2001). Empirical evidence shows that large firms tend to rely more on internal factors like formal R&D and accumulated technology (Yin and Zuscovitch, 1998) while small firms rely more on external linkages with customers and suppliers for their innovations (Lee, 1995). External linkage of SMEs with LEs is an important source for transfer of technologies, leading to innovative performance of SMEs (Rothwell, 1991).

Technology acquisition in developing countries can be related to three major sources, viz., adaptive, basic or innovative research through in-house R&D efforts, arm-length purchase of designs and drawings through payments of royalty or fees and imports of capital goods with embodied technology (Narayanan and Bhat, 2009). But small firms with limited in-house resources tend to be less R&D intensive and the ability of these SMEs to innovate depends on their access to external sources of resources needed for innovations. Most innovative small firms are involved in extensive and diverse links with a variety of external sources of knowledge and expertise (Freel, 2000). Acquiring knowledge and skills through external collaboration has become an effective and efficient way towards the success of innovations for SMEs (Kaminski *et al.*, 2008). Small firms need to have radical innovations as well as a large number of minor innovations and formal and informal channels as external technical sources are of crucial importance to them. Formal channels can be of technological licensing agreement whereas informal channels include suppliers, buyers, domestic R&D institutions or universities, government agencies and academic or technical literature (Lee, 1995).

A great variety of organizational modes can be adopted to access external sources of technology (Brockhoff, 1991; Milson *et al.*, 1996). These are shown in the Table 2.2.

2.3.4 Firm Level Technological Capabilities

The process of building firm-level technological capabilities in developing countries has following characteristics:

(1) *The process of acquiring technological capabilities is unpredictable* (Lall, 1992). Investments in capabilities, such as financial investments, carry considerable risk and the outcome is uncertain. Firms face technical difficulties and financial uncertainties, especially in research activities. Moreover, rarely can firms ensure against failure in capability building. The

implications of fundamental uncertainty are clear: the reality cannot be fully modelled and the direction of change never achieves equilibrium.

(2) *Capability building is an incremental and cumulative process* (Bell and Pavitt, 1993; Hobday, 1995; Aw and Batra, 1998) Enterprises cannot instantaneously develop the capabilities needed to handle new technologies; nor can they make jumps into completely new areas of competence. Instead, they proceed in an incremental manner, building on past investments in technological capabilities and moving from simple to more complex activities.

(3) *Capability building involves co-operation between agents* (Lall *et al.*, 1994; Mytelka and Farinelli, 2000) Firms rarely acquire capabilities in isolation. When absorbing imported technologies, they interact and exchange technical inputs with other firms (competitors, suppliers and buyers of output) and support institutions (research institutions, training bodies and SME extension services). Hence, interaction and interdependence between agents (i.e. collective learning) is a fundamental feature of capability building.

(4) *Success in building firm-level capabilities determines industrial success* (Ernst *et al.*, 1998) Differences in the efficiency with which firm-level capabilities are created are a major source of differences in comparative advantage between countries.

(5) *Capability building is affected by national policy and institutional factors* (Lall, 1992; Westphal, 2001) Firm-level learning can be stimulated by the trade, industrial and macroeconomic regime as well as by institutions providing finance, training and information and technological support. In general, macroeconomic stability, outward-oriented trade and investment policies, ample supplies of skilled general and technical manpower, ready access to industrial finance and comprehensive support from technology institutions are conducive to rapid capability building.

2.4 Key Elements of Technology Capability

There are three kinds of capabilities: internal; external; and strategic. These are interlinked and interdependent, because they are involved in a dynamic learning process. The extent to which companies actually possess these capabilities tends to increase with firm size. This seems mainly to be because increasing size brings increasing division of labour, allowing the firm to develop and devote the specialists skills required for the various dimensions of technological capability. Small, technology-based firms are the major systematic exception: they tend to have strong information and technology networking skills, but are not always as good at business skills. Many of the tasks of the support system in increasing technological capabilities involve helping SMEs act as if they were bigger than they actually are. In the best case, this becomes a kind of self-fulfilling prophecy, where SMEs grow to become large firms (Mordchelles *et al.,* 1986).

Howells (1994) description is a static one. His concern is to show the interdependence of tangible and intangible assets in underpinning firms' competitiveness. He therefore makes the distinction between these two kinds of assets central to his model and treats tacit knowledge as a particularly special category of intangible assets.

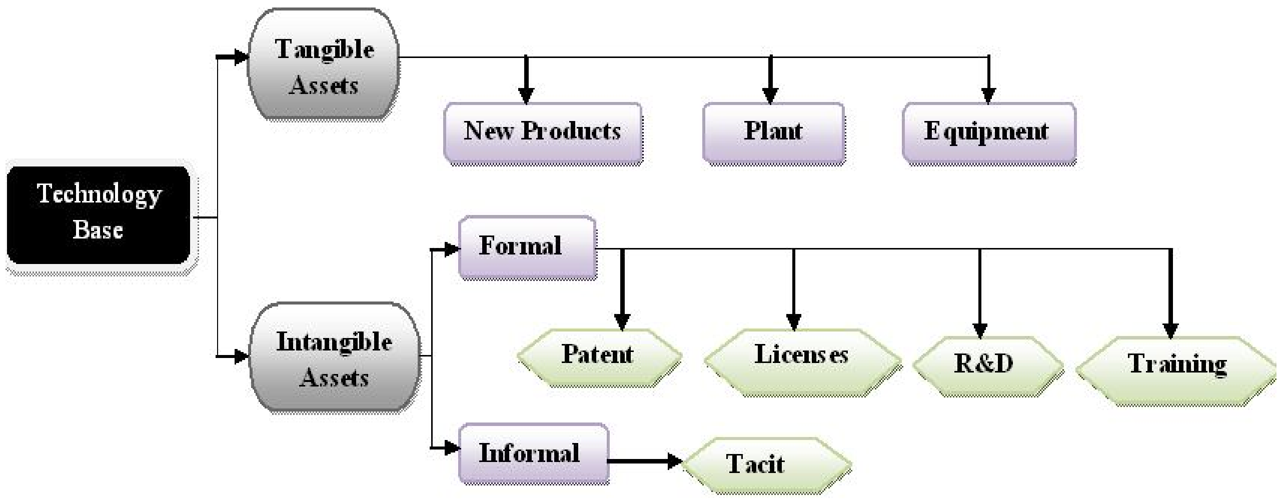

Fig 2.1 Static approach to Technology Capability (Shan, 2010)

Bessant and Dodgson (1996) approach is dynamic. They define their terms as

- **Resources** All the assets in the firm which enable firms to operate, including tangible and intangible assets, skills, knowledge, organisation, links with other firms.

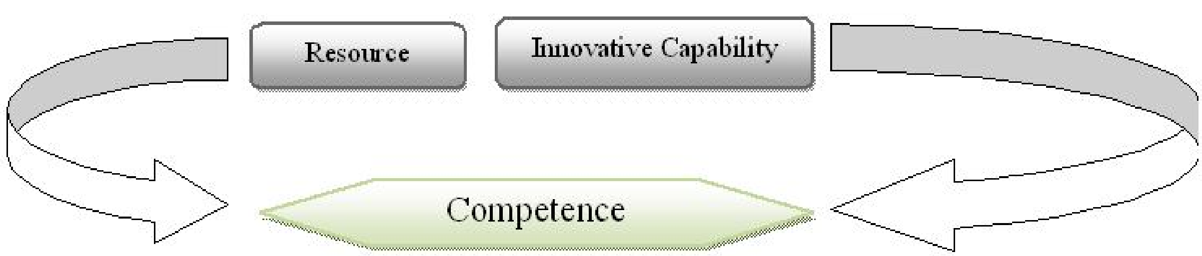

Fig 2.2 Dynamic approach to Technology Capability (Shan, 2010)

- **Innovative Capabilities** Features of firms and their management which enable them to define and develop competences to create competitive advantage.
- **Competences** That focused combination of resources which enables firms to differentiate themselves from their competitors.

2.4.1 Strategic Capabilities

In addition to providing a key part of the 'search intelligence' needed to develop and manage technological capabilities, the strategic functions are the major interface with the firm's business capabilities. In particular, this is where the understanding of customer needs and desires, technological opportunities and the company's own capabilities need to be matched together. This defines the core competencies of the firm. Product strategy needs to be hammered out here, based on inputs from the three areas mentioned. The salient point from an innovation perspective is that the ability to wrap technological issues into business strategy-and vice versa-is an important capability. This requires an awareness of business and technology issues that is often not found in the same person: a problem, especially in small owner-managed companies. Increasingly, this fact is being reflected in education, awareness and support programmes aimed at capability development.

- Search for market opportunities.
- Understand and manage the fit between the firm's capabilities and market need (Arnold, 1997).

2.4.2 Internal Capabilities

Internal capabilities have three main elements

- Managing the tangible technology base
  - Products
  - R&D facilities
  - Appropriate plant and equipment
- Developing and managing intangible resources
  - Codified intellectual capital
  - Qualification and skills profile adapted to the needs of the firm
  - Tacit knowledge

- Creating the organisation needed to make effective use of these assets in pursuit of the company's business mission
    - Technology management capabilities
    - Change-management ability
    - Co-ordination among internal 'owners' of capabilities

The tangible basis of companies' internal technological capabilities is their products and the design and production facilities employed, which need to be adequate to meet competitive needs. Choice, maintenance and renewal of these are based on design and engineering skills. In the smallest firms, these often belong to the people who are also the owners and managers. The pressure of their combined roles can mean that the technology used is outdated or otherwise sub-optimal (Arnold, 1997; Keith, 1997).

2.4.3 External Capabilities

External or networking technological capabilities involve:

- Accessing external knowledge
    - Science
    - Technology, techniques
    - Artifacts, training
    - Know-how, tacit knowledge
    - Information resources
- Managing the producer/user relationship which is central to successful innovation
- Accessing other partners who have useful complementary assets and capabilities
    - Complementary knowledge
    - Complementary production
    - Complementary supply chain role

While it is tempting to dismiss as mere fashion the current tendency to describe almost any external relationship of a firm as 'networking', the role of such external relations in successful innovation and in learning is extremely important (Arnold, 1997).

2.5 Technological Capability in SMEs

Technological capability is crucial for the ability of small and medium manufacturing enterprises to make a significant contribution to local industrial development (Caniels and Romijn, 2001).

Among firms of different sizes, SMEs are generally more flexible, adapt themselves better, and are better placed to develop and implement new ideas. The flexibility of SMEs, their simple organizational structure, their low risk and receptivity are the essential features facilitating them to be innovative (Harrison and Watson 1998). There is substantial evidence to show that a number of SMEs in a wide variety of sectors do engage in technological innovations, and that these innovations are likely to be an important determinant of their success (Hoffman *et al.*, 1998). However, the ability and innovative capacity of SMEs varies significantly, depending on their sector, size, focus, resources, and the business environment in which they operate (Burrone and Jaiya 2005). Particularly innovation in the manufacturing sector is a very complex process which is propelled by numerous factors (Becheikh *et al.*, 2006).

This leads us to the question-what drives manufacturing SMEs to technologically innovate? If a firm has to technologically innovate, it should have in-house technological competence in the form of technically qualified and motivated entrepreneurs or managers with innovative ideas and technically skilled employees. Similarly, there must be a market demand for the innovated products in the form of an explicit customer demand or implicit market opportunities. Of course, the relative importance of these internal as well as external factors might vary from firm to firm or from industry to industry or even from economy to economy and from time to time (Subrahmanya *et al.*, 2010).

2.6 Assessment of Technology Capability

The relation between technology innovation capability (TIC) and firm performance is more complex than what is generally assumed. Although many empirical studies have been done (Zahra, 1996; Deeds *et al.*, 1997, 1998; DeCarolis and Deeds, 1999), little consensus has developed as to the exact relation between TIC and performance.

Many researchers use R&D expenditures, patents or a combination of the two as indicators of firm‟s TIC (McCutchen and Swamidass, 1996; DeCarolis and Deeds, 1999), others used measures such as citation counts (Deeds *et al.*, 1997, 1998; DeCarolis and Deeds, 1999), absorptive capacity (Cohen and Levinthal, 1990).

2.6.1 Measurement of Firm competitive performance

Accounting measures such as sales growth, return on sales, return on assets, and return on equity are commonly used performance indicators in a range of fields such as entrepreneurship (Shan, 2010) corporate governance (Dalton *et al.,* 1998), international management (Hitt *et al.,* 1997), and technological capability (Franko,1989; Shan, 2010). Although the firm performance in financial terms is always the best indicator, firms would not easily reveal any confidential financial information and different firms might adopt varied accounting conventions in their inventory valuations, depreciation, and salaries computation. Alternate measures should be used to secure adequate responses. Therefore three other types of performance indicators can be used: innovation performance, sales performance and product performance. These measures are widely adopted in different innovation studies (Guan and Ma, 2003).

- Innovation performance is measured in terms of the number of commercialized new products expressed as a percentage of all products in the company over the past three years.

  The focus on innovation based performance is important because the speed of product development, newness of products and number of new products are all associated with the firm resource investment and capabilities that drive product associated outcomes. Therefore, new product innovativeness, which refers to the firm's whole range of products, defined here as the relative newness and timeless in the development and frequency of its new product introduction (Sok and O'Cass, 2011).
- Sales performance is measured in terms of the average annual sales growth over the last three years.
- Product performance is measured through six dimensions: average concept-to-launch time, quality level, cost advantage, market competitiveness, unique technology characteristics and/or special product manufacturing process, price/function advantage.

2.6.2 Measurement of TIC related to investment capability

The survey tool enquires about the average proportion of spending made in the different innovation activities to the firm's total sales during the last three years (Shan, 2010). The investment capability is measured by means of seven-point scales, where the scales are labeled as 1*(<1%)*, 2 *(1% - 3%)*, 3*(3% - 5%)*, 4*(5% - 7%)*, 5*(7% - 10%)*, 6*(10% - 20%)*, 7*(>20%)*. These innovation activities are draw upon the Oslo Manual (OCDE-Eurostat, 1997) to detect the technological investment capability, which consists of seven dimensions:

- purchasing of tangible technology, such as machinery and equipment;
- purchasing intangible technology, such as patent and license;
- Conducting contracted R&D activities (sub-contracted R&D and joint R&D activities);
- In-house R&D;
- Knowledge depending, such as training, inviting experts from outside for problem solving, trials and experiments;
- Improvement of existing product and process technology;
- Marketing of new or improved products.

2.6.3 Measurement of TIC related to production capability

In order to detect technological production capability, managers are asked in the questionnaire to assess their firm's production capability related to generating innovations compared to the competitors in the same sector on 7 point-scale, ranging from (1) very unsatisfactory to (7) very satisfactory. Those technological production capabilities are draw upon the literature and adjusted after pre-testing with the academicians and industrial practioners. Finally, the following eight dimensions are utilized to measure production capability:

- The improvement and adaptation of production process;
- The improvement of product;
- The design of changes to production organization or market need;
- The improvement of product quality;
- The imitation of technologies brought in by competitors;
- The imitation of innovation in products developed by competitors;
- The development of the firm's own technology (machinery, processes, etc.);
- The design of new products (Shan, 2010).

2.6.4 Measurement of TIC related to linkage capability

The level of impact of various links on firm's technological development are assessed. Linkage capability is also measured on 7 point-scale, where 7 indicated the highest level of influence and 1 the lowest level of influence. Those internal and external links are:

- R&D department with production department;
- R&D department with marketing department;
- External linkages with suppliers of equipment, materials, components, or software;
- External linkages with clients or customers;
- External linkages with competitors or other firms in the sector;
- External linkages with private consultancy organizations;
- External linkages with the universities or other higher education institutes;
- External linkages with the government research institutes (Shan, 2010).

2.7 Studies and Models in the Research Area

Some of the studies theoretical models in the context of technological innovation capability in MSMEs are presented as follows:

Clark and Fujimoto (1991) analyzed that firm performance be measured through different indicators. The two major performance measures used are accounting measures and market value. Accounting measures include sales growth, return on sales (ROS), return on assets (ROA), and return on equity (ROE). Each measure of firm performance has advantages and disadvantages and each provides researchers with a perspective of success.

Lall (1992) suggested that 'Technological knowledge is not shared equally among firms, nor it is easily imitated by or transferred across firms. Transfer necessarily requires learning because technologies are tacit, and their underlying principles are not always clearly understood. Thus, simply to gain mastery of a new technology requires skills, effort and investment by the receiving firm, and the extent of mastery achieved is uncertain and necessarily varies by firm according to theses inputs'.

Romjin (1997) addressed the lack of objective quantitative measurement and testing for TIC. Using data from a survey among capital goods manufacturers in Pakistan, the researcher developed quantitative proxies for technological capability and various learning mechanisms that are believed to contribute to its emergence. The study revealed that small-scale light engineering workshops employing roughly five to 50 persons and using a variety of general-purpose machinery such as lathes, drills, grinders, welding sets, hacksaws, power presses, angle benders and sheet-metal rollers, etc. form the dominant mode of production in the farm equipment sector in a great majority of developing countries. This is also very much the case in the Pakistan

(Punjab) the area from which the sample for this study was drawn. The sample size was set at 102 firms. The analysis demonstrated that the qualitative case study approach that has dominated the literature on capability building to date is not the only feasible method for analyzing the question of how firms go about the acquisition of technological capabilities. An important result from the analysis was that it supports the central assertion in the extant capability literature that "technological efforts" made by firms to assimilate and improve technology are very important for capability building.

Chiesa *et al* (1998) developed a technical innovation audit framework encompassing several significant elements, such as product innovation, product development, process innovation, technology acquisition, leadership and resourcing. The framework focused on core processes and enabling processes to delineate technological innovation. The authors concluded that more evidences are needed to test the validity of the framework (e.g., overlapping between product innovation and development). Besides, other areas such as learning, organizing and strategic planning that were central to a firm's innovation capability need to be stressed.

Wong (1999) suggested that latecomers (especially the small units) pursue a certain strategy to develop technological capabilities: first they start developing process-capabilities, followed by product design capabilities and finally new product creation-/branding-capabilities. 'This is a reversal of the normal sequence of value chain activities pursued by large established high-tech firms in advanced countries'.

Burgelman *et al* (2001) proposed the innovative capabilities audit framework included five audit dimensions: (a) Resource availability and allocation (b) Capacity to understand competitor innovative strategies and industry evolution (c) Capacity to understand technological developments (d) Structural and cultural context (e) Strategic management capacity.

Linsu Kim (2002) proposed that 'Technological Capabilities (TCs) refers, to the ability to make effective use of technological knowledge in production, engineering and innovation. It also enables a firm to create new technologies and to develop new products and processes in response to their changing economic environment. Technological learning is the process of building and accumulating TCs'.

Wignaraja (2002) suggested that 'technology index' is a useful shorthand device to quantify inter-firm differences in technological capabilities. Econometric analysis of the determinants of the 'technology index' and export performance produced some interesting results. Firm size, technical manpower, employee training and external technical assistance showed significant and positive effects on the technology index, but firm age and foreign equity were not found to be significant. A comparison of large firms with SMEs showed that the latter have lower levels of capabilities, are less export-oriented, have less foreign equity, conduct less training and make less use of external technical assistance. The analysis of export performance indicated that foreign equity and the technology index are significantly and positively associated with export shares. Firm size, firm age and technical manpower were not significant.

Guan and Ma (2003) classified the innovation capabilities into seven dimensions: (1) learning (2) R&D (3) manufacturing (4) marketing (5) organizational (6) resources exploiting and (7) strategic capability, all of them including a certain number of dimensions. Innovation capability is a special asset of a firm. It is tacit and non-modifiable, and it is correlated closely with interior experiences and experimental acquirement. TICs are a kind of special assets or resources that include technology, product, process, knowledge, experience and organization.

Agboolac *et al* (2004) examined the level of availability of technological capabilities in the telecommunication industry in Nigeria. Purposive sampling method was used to acquire data from five major sectors in the industry, which were: telecommunications service providers, equipment suppliers, training institutions, industry regulators, and a section of private sector which was referred to as other providers. The questionnaires were administered to 110 respondents with a retrieval rate of 86%. In this study, 'Investment Capability', 'Production Capability', 'Major Change', 'Linkage Capability', 'R&D Capability' were used as input variables. The results obtained showed that five technological capabilities were needed for an efficient telecommunications system. They were investment capability, service production capability, major change capability, linkage capability and R&D capability. The study showed that investment and service production capability were in abundant supply in the industry. Major change capability was found to be available but in short supply, while linkage and R&D capabilities were found to be rarely available.

Yam *et al* (2004) investigated the link between technology innovation capabilities (TICs) and competitive performance indicators. With the assistance of Beijing Science and Technology Committee (BSTC), the survey received responses from 237 firms. Of these firms, 213 questionnaires were usable yielding a response rate of 56.8%. These were composed of 73 large firms, 79 medium-sized firms, and 61 small firms. A great majority of respondent firms were state-owned enterprises (SOEs). The sample distributions by industry sector were: electronic communication (16.4%), textile, clothing and leather (11.7%), chemicals (9.4%), instruments apparatus (8.5%), and ordinary machine manufacturing (8.0%), which were the five highest responding sectors. It was believed that the sample included the representative firms from various sectors that possessed a higher innovation capability and market force. The variety of industry types ensures that the findings did not relate to specific industries. The audit results verified that there exists a positive correlation between TICs and the competitive performance of Chinese firms. R&D and resources allocation are the two most important TICs that have been playing a pivotal role in enhancing the innovation rate, sales growth and product competitiveness of Chinese firms.

Gaun *et al* (2006) suggested a framework including seven capability dimensions, namely learning capability; R&D capability; manufacturing capability; marketing capability; resource exploiting capability; organizational capability and strategic capability. Learning capability is an enterprise's ability to identify, assimilate, and exploit knowledge internally and from an external environment. R&D capability refers to the integration of the following four aspects: R&D strategy constitution, R&D project implementation, R&D project portfolio management and R&D devotion. Manufacturing capability refers to the ability to transform R&D results into products, which can meet market needs, design requirements and production economics. Marketing capability is an enterprise's ability to publicize and sell products on the basis of understanding consumer needs, competition position, cost and benefit, and acceptance of innovation. Resources allocating capability ensures that an enterprise has sufficient capital, professionals and technologies in the innovation processes. Organization innovating capability refers to harmony amongst departments, organization response to opportunities, organization culture, organization mechanism, and management methods, etc. Strategy planning capability is an enterprise's ability to understand all kinds of external relations and to acclimatize to external environment. These seven technological innovation capability dimensions constitute the basic components of innovation including technology, production, management and market etc.

Pun *et al* (2006) explored the relationship between technology transfer activities and innovation performance with special reference to Chinese industrial firms. It was based on a nationwide survey covering 2334 Chinese industrial firms. For facilitating the analysis, the surveyed firms were divided into two groups of 888 general industrial firms and 1446 high-tech firms. The empirical results partly verified the hypotheses in this study to some extent. Inspite of this, the following major findings could be made:

(i) Empirical analyses showed that the adoption of transferred and/or purchased technologies had both positive and negative impacts on Chinese firms. It seemed impossible to give a mono-causal explanation for the observed results.

(ii) Technology transfer activities would generally improve innovation performance of most industrial firms, but it might also impede the innovation performance of high-tech firms.

However, technology transfer was found to be a key contributor to innovation performance, competitiveness and economic development of the country. It was also a high-risk process since there was no guarantee that a technology development project would result in successful product innovation or the investment would generate sufficient returns.

Kong (2008) suggested that technological innovation capability is the driving force of a firm's innovation and defines the roots of a firm's long-term competitive advantage. It consists of innovation input ability, R&D capability, manufacturing capabilities and marketing capabilities. Successful technological innovation depends on both technological capability and other critical capabilities, such as organizational, marketing, capital funds, manufacturing, strategic planning, and resource allocation. But promoting technological innovation must be established on the basis of accurate analysis and evaluation for technological innovation capability, the evaluation of technological innovation capability seems particularly important. The technical innovation capabilities of a firm are based on multiple criteria, comprising both quantitative and qualitative criteria.

Figueiredo (2008) preferred another type of TC’s measure in his Brazil's case study. On the basis of a Lall (1995) type of taxonomy, he distinguished between "routine" production capability and ‘innovative’ TC’s. In this study he focused specifically on two groups of firms: electro-electronic firms and suppliers, and bicycle and motorcycle firms and suppliers. He measured TCs by the type of activity (process) a firm was able to do on its own, at different points in time, identifying not only the manner and level of difficulty, but also the time-scale that each firm needed to reach a higher capability level. He introduced, then, another important issue that was 'time' needed for capability accumulation.

Zheng *et al* (2009) examined the role of technological capability in product innovation. Building on the absorptive capacity perspective and organizational inertia theory, the authors proposed that technological capability has curvilinear and differential effects on exploitative and explorative innovations. A random sample of 500 firms from a list of high-technology companies located in Shanghai and its surrounding areas (Jiangsu and Zhejiang provinces) provided by a business research firm. Responses from 195 firms (390 informants) were obtained. Three cases with excessive missing data and the remaining 192 cases containing full information of the variables dropped under the study. Therefore, the final sample consisted of 192 firms (384 informants), for an effective response rate of 38.4 percent. Of the 192 firms, most (75.9%) were small or medium in size with 500 or fewer employees, and 77.9 percent had annual sales revenues of more than US$3 million. In addition, 34.9 percent were Chinese firms, 31.8 percent international joint ventures, and 33.3 percent wholly foreign owned firms. The largest industry segment was information technology (33.3%), followed by electronics (27.1%), computer equipment (18.8%), and telecommunications (11.5%).The findings supported the proposition that though technological capability fosters exploitation at an accelerating rate, it has an inverted U-shaped relationship with exploration. That is, a high level of technological capability impedes explorative innovation. Strategic flexibility strengthens the positive effects of technological capability on exploration, such that when strategic flexibility is high, greater technological capability is associated with more explorative innovation.

Lau *et al* (2010) suggested an auditing framework that can help to determine the suitable links between innovation capabilities and business performance; and to enable the auditor to determine whether good practice is in place. The seven TICs in this study include learning, R&D, resources allocation, manufacturing, marketing, organization and strategic planning capabilities. Manufacturers from electronics, electrical appliances, toys, machinery and watches & clocks industries in the studied region were selected as the sample frame in this survey. The survey questionnaires were mailed to the selected 1,200 firms and 1,153 were reached (47 letters were undelivered because of changed address or the contacted person had left the firm) of which 12 firms were not in the targeted industries. Out of these 1,153 successfully contacted firms, 202 firms responded to the survey. This contributed a response rate of 17.7%. After data cleaning process, 2 incomplete responses were deleted. Finally, 200 effective questionnaires were analyzed in this study. The study revealed that the current innovation policy seems to be ineffective in enhancing the TICs of Hong Kong manufacturers; it is difficult to recruit experienced R&D professionals in Hong Kong. However, there is a lack of sufficient know-how and knowledge to start and sustain the technological development within the companies.

Ortega (2010) proposed the role of technological capabilities in moderating the relationship between competitive strategies and firm performance using a sample of 253 companies from the information and communications technology industry in Spain. In this study used an initial sample frame of 1847 firms. The author received 253 valid questionnaires; an acceptable response rate of 14%. With regard to the sampling error, for a confidence level of 95% the study shows an error of 5.72%. This study examined the interaction between technological capabilities and competitive strategies and their combined relationship to firm performance. Specifically, the results indicated that in dynamic and hostile environments, technological capabilities have a positive influence on firm performance.

Yam *et al* (2010) suggested the impact of technological innovation capabilities (TIC) on firms' competitive performances. This paper adopted a study framework of innovation audit to examine the relevance of TIC on the innovation performance of the electronics industry in Hong Kong (HK)/Pearl River Delta region. To select the sample population, the authors used the Directory of HK Industries published by HK Productivity Council. The targeted respondents of the survey were senior product development managers, vice presidents, or directors listed on the directory. They were requested to fill out the questionnaire. Follow-up faxes and phone interviews were conducted by a trained interviewer to ensure data quality. Of the 1,012 firms selected from the directory, 934 were reached (78 letters were undelivered because of a change of address or the contact person having left the firm). Of the 934 targeted firms successfully contacted, 81 effective responses were collected. This is a response rate of 8.7 percent. The results verified that R&D, resource allocation, learning, and strategy planning capabilities can significantly improve the innovation sales. R&D and resource allocation capabilities can also significantly improve new product introduction.

Baark (2011) suggested theoretical perspectives which underscore the role of technological and innovation capabilities. The study extended the knowledge of the role of various sources of innovation and technological innovation capabilities in the innovation performance of firms, particularly as they appear in newly industrialized regions. Using a firm-level analysis, this study provided empirical evidence suggesting that specific sources of innovation are particularly effective in enhancing the firm's innovation capabilities and in turn product competitiveness. On the other hand, this research also found that sourcing innovation from research organizations outside PRD have a negative effect on marketing but a positive effect on R&D capability. The marketing knowledge from research organizations outside PRD may not be appropriate to the local industry. Moreover, it became apparent that contributions from research organizations within PRD have little or no effect on a majority of technological innovation capabilities in firms.

This study also found that resource allocation, marketing and organizing capabilities improve product competitiveness, while other types of capabilities do not.

Domenea and Pietrobelli (2012) explored the evolution of the manufacturing sector in three Latin American countries adopting the microeconomic focus of technological behaviour and firms' learning processes. To this aim, the research measured technology capabilities (TCs) at the firm level and explored their determinants. 746 firms in Argentina and 697 firms in Chile (Argentina's and Chile's surveys covered Food Processing, Textiles, Garments, Chemicals, Non Metallic Mineral Products, Machinery and Equipment, Other Manufacturing etc., 1642 firms in Brazil (Brazil's survey considered Auto Parts, Chemical, Food Processing, Electronics, Furniture, Garments, Machinery, Shoe and Leather Products and Textiles). The study verified that the three countries' manufacturing enterprises have different levels of technology capabilities (TCs). The presence of remarkable outliers within specific sectors that have high levels of technology innovation (TI) as a result of different levels of accumulation of TCs makes generalizations hard. Secondly, firm size was found to be relevant to building capabilities. In Argentina, Brazil and Chile, larger firms have higher TIs than medium and small ones. Nevertheless, when the size variable was analyzed within the TCs-exports system, size remained an important factor for both building capabilities and exporting for Brazil and Chile.

2.8 Conceptual Model

Based on the examination of available literature and scope of present research, a conceptual framework has been derived to understand the complexities involved in managing technological innovation capability initiatives at firm level and their linkages with performance parameters in manufacturing industry. The conceptual framework is presented in Figure 2.3.

The detailed review of literature has brought *three* main *input factors* for effective implementation of technology innovation capability initiatives in the manufacturing industry.

In this present work these input factors have been referred to as *'investment capability'*, *'production capability', and 'linkage capability'*. Further, it is proposed to focus on *three* main *output performance parameters* to assess the contribution of input factors towards firm's performance improvements in the industrial sector. The output performance parameters to be used in the present research include, *'innovation performance'*, *'sales performance*, and *'product performance'*.

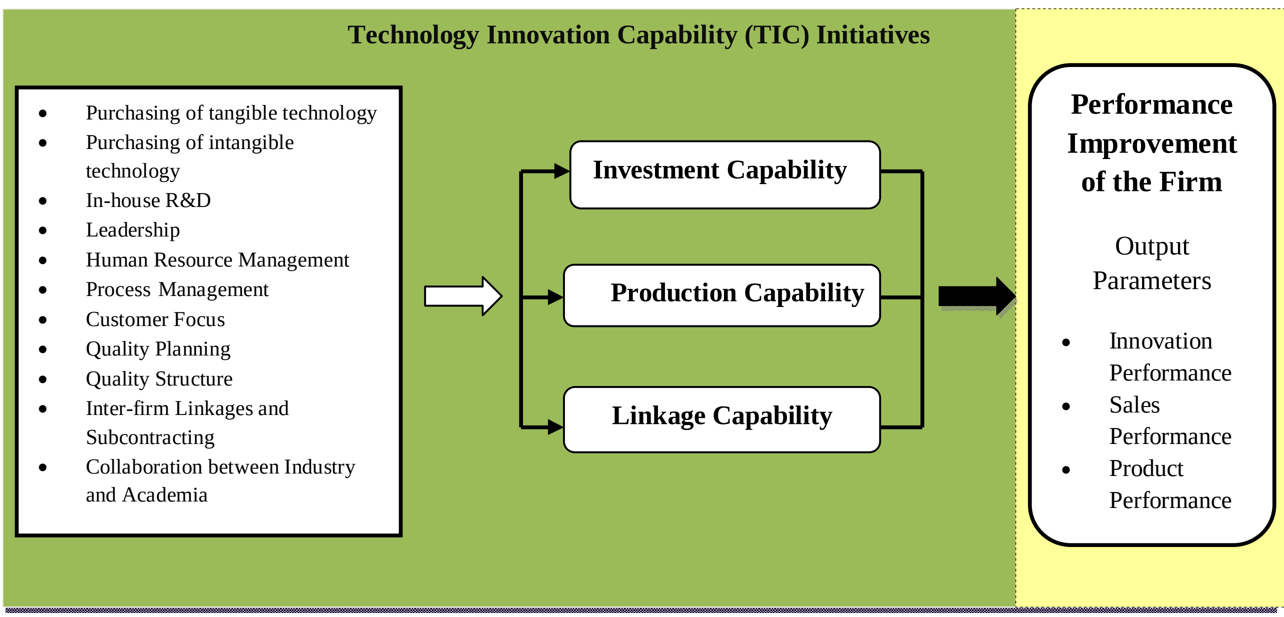

Figure 2.3 Conceptual Framework showing interlinkages between Technological Innovation Capability and Firm's Performance

In the present study, it has been hypothesized that the key input parameters *(Technological Innovation Capability Input Factors)* have a significant influence on the three output performance parameters. It is hypothesized that the different issues under each input factor have a positive association with each development indicator (output parameter).

The present work assesses the status of each of these factors in the selected class of industry and evaluates the contributions of various technological innovation capabilities initiatives towards performance improvements.

2.9 Gaps in the Literature

An extensive review of the concepts, taxonomy and related facets of technology capability initiatives in the manufacturing organizations especially SMEs has been carried out. The review of past literature indicates sufficient gaps for the conduct of present research work.

The main limitations in the existing approaches are as follows:

- The development of technological capabilities has attracted extensive attention both from the theoretical and empirical viewpoint. In addition, extensive research on the development of technological capabilities is carried out not only in emerging countries but also in advanced countries. Most of such research in emerging countries is based on the development experiences of newly industrializing economies. Little is known about the process of building up technological capability in non-industrialized countries such as China, India and Indonesia.
- Further, very few empirical studies and quantitative research have been reported to support the theoretical findings for MSMEs. There are remote cases where the relative impact of technology capability initiatives on performance improvements, especially in the small sector manufacturing sector have been reported. Although many empirical studies have been done, little consensus has developed as to the exact relation between TIC and performance.
- Companies currently compete in the environment with business and innovation globalization and the diffusion of technology. However, the research on technological capability development in such a small and medium enterprises is inadequate.

2.10 Concluding Remarks

Due to research gaps existing in the previous studies of technological capability's development and the fast change of the business environment, it is necessary to explore the process of technological capability generation in SMEs.

The goal of this dissertation is to explore the process of technological capability development for manufacturers in SMEs in order to close the research gaps mentioned above. During the analyses of the TIC development process, the main determinants in this process are investigated from the perspective of manufacturer in SMEs.

It can be concluded that SMEs should perceive the development technology innovation capability program of conditions that encourage firm's performance included innovation performance, sales performance and product performance. A conceptual framework has finally been developed and presented to understand the complexities involved in managing technological innovation capability initiatives at firm level and their linkages with performance parameters in manufacturing industry.

The next chapter introduces overall design of the study. It describes the various phases of research and the methodology adopted for carrying out the present work.

CHAPTER - III

DESIGN OF THE STUDY

3.1 Introduction

This chapter introduces the overall design of the study, which includes methodology to be adopted for carrying out the research work as well as various phases of the study. The details of work to be done in each phase; the methodology adopted, statistical tools and models to be used in the work have also been described.

3.2 Objectives and Issues

The main objective of the present work is to develop an approach to analyze the impact of the three sets of technology capabilities on firm competitive performance along three distinct lines: innovation performance, sales performance and product competitiveness through efficient technology innovation capability programs. Literature highlights the following areas and issues as critical to the success of the present research work:

- **Investment Capability**- It comprises of the following sub-factors:
  - ➢ Purchasing of tangible technology
  - ➢ Purchasing of intangible technology
  - ➢ Inhouse R&D
- **Production Capability**- It comprises of the following sub-factors in terms of quality management:
  - ➢ Leadership
  - ➢ Human Resource Management
  - ➢ Process Management
  - ➢ Customer Focus
  - ➢ Quality Planning
- **Linkage Capability-** It comprises of the following sub-factors:
  - ➢ Inter-firm Linkages and Subcontracting
  - ➢ Collaboration between Industry and Academia

3.3 Phases of Research

The present study will employ both quantitative and qualitative research approaches. The quantitative approach will utilize a series of statistical techniques. The results obtained from quantitative study and literature review will be synthesized to develop a systematic plan using a qualitative research methods. Based on flexible systems methodology, the research work will be carried out in three phases, also shown in Figure 3.1,

Phase I : Clarifying the context

Phase II : Understanding and assessing the situation

Phase III : Evolving a management process

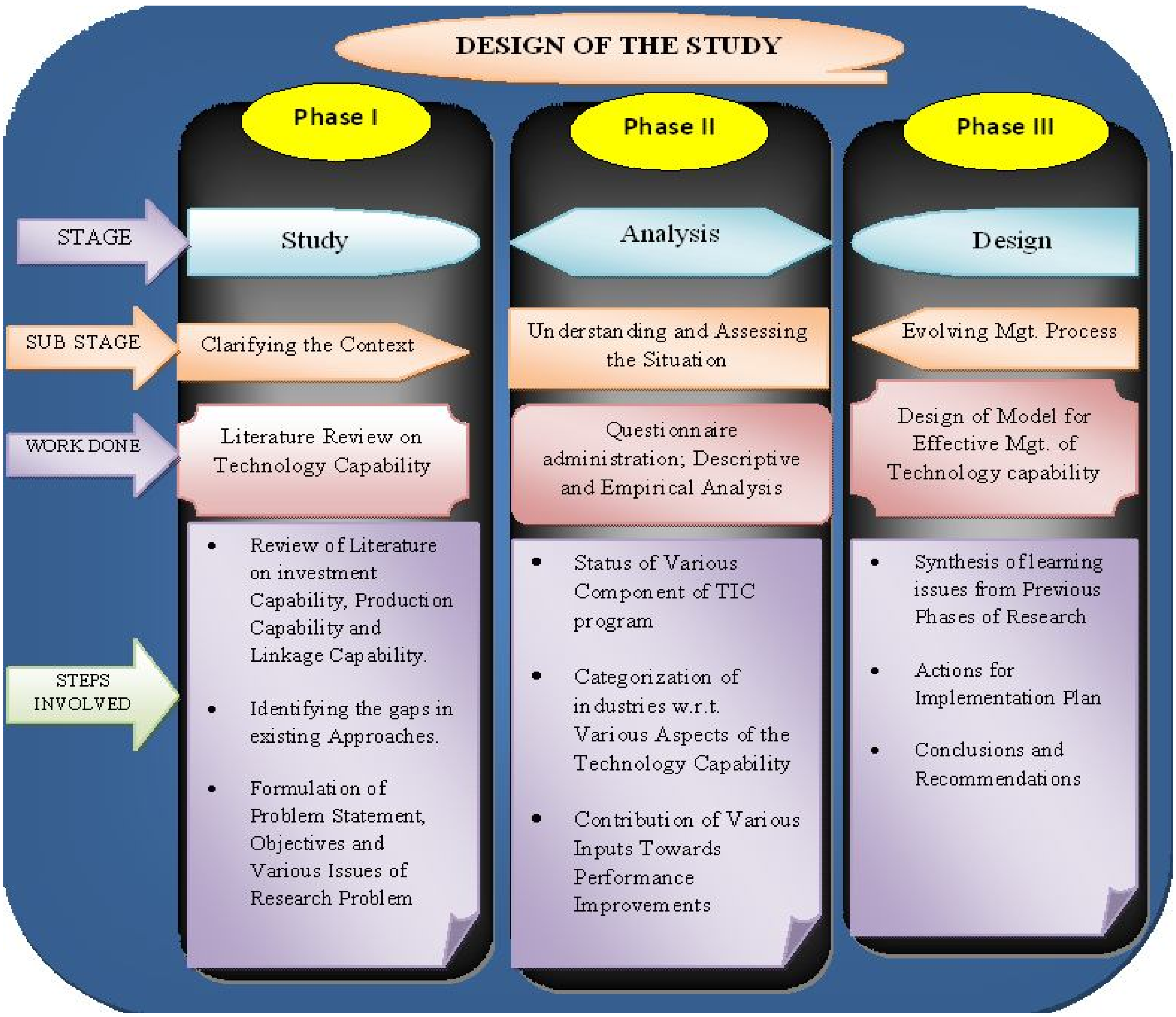

Fig. 3.1 Phases of Research

3.4 Clarifying the Context

This phase reviews the literature on technology development capabilities of manufacturing industry with regards to investment capability, production capability and linkage capability. Tactical issues for managing innovations and strategies for bridging the technology capability gap have been assessed. Literature review regarding economic, technical, regulatory and other related issues regarding technology innovation capability upgradation has also been carried out.

3.5 Understanding and Assessing the Situation

The study has been carried out in small scale manufacturing units dealing with cutting tool, machine tool and auto-component in Patiala region. In the research work, the questionnaire based survey research technique has been employed and questionnaire was sent to a large number (40 units) of small scale units in Patiala region and out of these a total of 25 fully filled and usable questionnaires were received and have been taken for analysis.

3.5.1 Research Approach

The research approach (Qualitative, Quantitative, or Mixed Methods) is decided based on interrelated levels of decisions which when made dictate the approach and the research design process. These decisions are based on which knowledge claims, strategies of inquiry, and research method used.

‘A quantitative approach is one in which the investigator primarily uses post positivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data’. ‘A qualitative approach is one in which the inquirer often makes knowledge claims based on constructivist perspectives (i.e. multiple meaning of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e. political, issue orientated, collaborative, or charge orientated) or both. It also uses strategies of inquiry such as narratives, phenomenology’s, ethnography’s, grounded theory studies, or case studies. The researcher collects open-ended, emerging data with the primary intent of developing themes from the data’. ‘A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g. consequence-orientated, problem-centered, and pluralistic). This approach employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problem. The data collection also involves gathering both numeric information (e.g. on instruments) as well as text information (e.g. on interviews) so that the final database represents both quantitative and qualitative information' (Creswell, 2003).

Based on these definitions and the work of O'Leary (2004) this can be summarised as shown in Figure 3.2.Therefore, based on Figure 3.2, both Quantitative and Qualitative Research Approach would appear to be the approaches to be used in this thesis.

3.5.1.1 Quantitative Research Approach

Figure 3.3 shows the Quantitative Research Approach Model as described by Bryman and Cramer (2005). This is comprised of Theory, Hypothesis, Operationalisation of Concepts, Selection of Respondents, Survey or Experimental Design, Data Collection, Analysis and Findings. Research approaches can be categorized into two other types- survey based and non survey based. Since our study will include collecting of data from industries, so the approach to be followed in this thesis will be survey based research approach.

There are different types of survey-based research (Churchill, 1995). An overview of these is presented in Figure 3.4. 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 is 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.

Fig. 3.2 Research Approach Flow Charts (O'Leary, 2004)

Questionnaire Development: For effectively conducting the survey, the first task is to design a questionnaire. A questionnaire has been prepared through extensive literature review. A relevant and detailed questionnaire containing objective type questions with multiple choice answers pertaining to the desired conceptual framework has been designed. Information on various aspects related to this research work in the small scale manufacturing industry relating to tool and auto-component manufacturers of Patiala has been sought in it. Scale items has been used in the analysis, since the research interest is to examine the effects of independent variables on dependent variables.

Questionnaire Pre-testing and Validation: After preparing the questionnaire through extensive literature review, it has been pre-tested through peer review from academicians and practitioners from the industry. To ensure the relevance and effectiveness of the questions to the manufacturing industry, the questionnaire has been pre-tested on a representative sample of industry. The suggestion received has been incorporated to make the questionnaire more relevant to the purpose so that it may bring out key outcomes. The objective is to confirm that responses

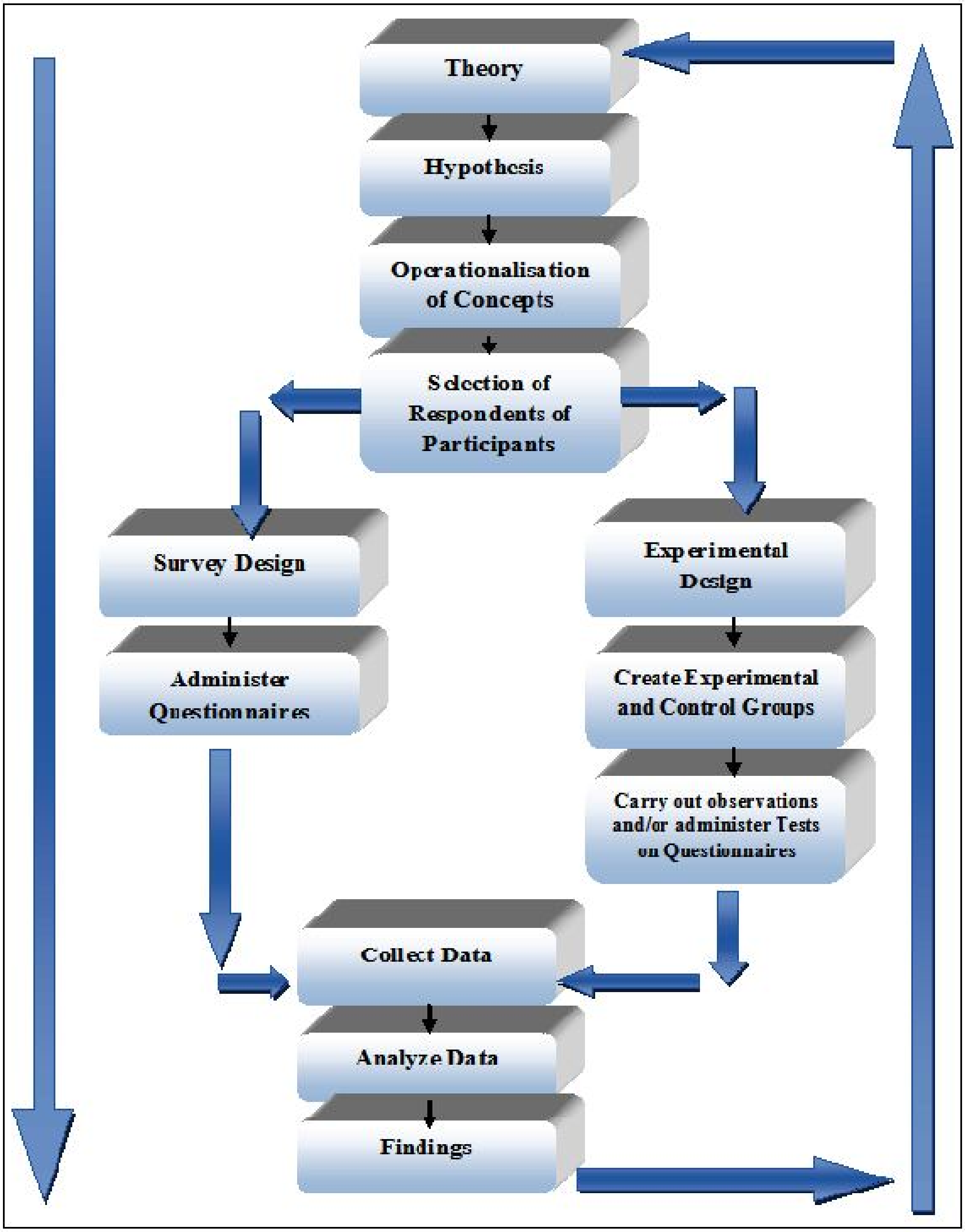

Fig. 3.3 Quantitative Research Approach Model (Bryman and Cramer, 2005)

that will be obtained are based on correct interpretation of the questions. Cronbach's Alpha has been assessed for item-to-total correlation for validation (reliability testing).

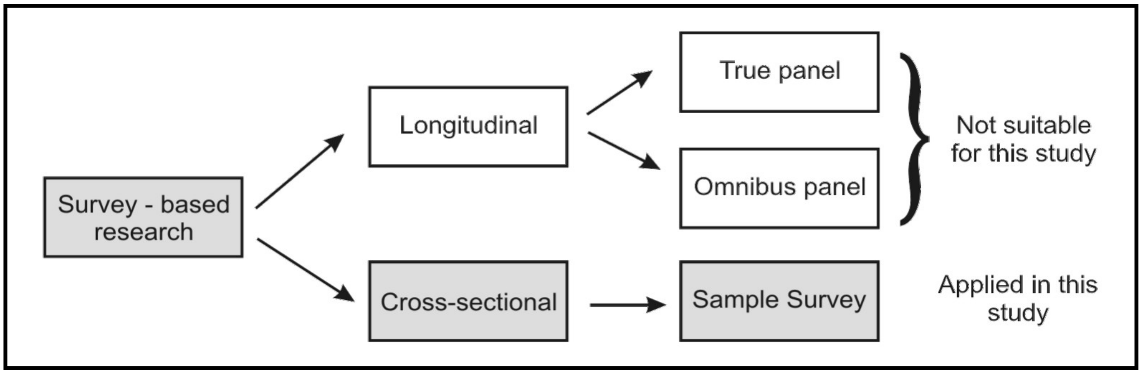

Figure 3.4 Types of Survey Based Research

3.5.2 Conceptualisation and Instrument Design

With the exception of facts (like a persons age), a survey does not collect data, it creates it. The answers to the survey are a description (this is a descriptive survey) of the respondents. Conceptualisation and instrument design deals with ensuring that the concepts, in this case of technology development, are converted into questions such that relevant empirical data can be analyzed. In addition, the quality of the survey measurement is very important. Two techniques cover this, reliability and validity (Babbie, 1990).

3.5.2.1 Reliability and Validity

The quality of the survey research is established by examining the reliability and validity of the survey (Litwin, 1995).

3.5.2.1.1 Reliability

Measurement error is related to how well or badly a survey achieves its purpose in a given population. According to Litwin (1995) reliability is:

'A statistical measure of how reproducible the survey instruments data is'.

There are three types of reliability:

Test-retest reliability (or Stability Reliability) – This is the most commonly used indicator of instrument reliability. The same set of respondents are measured at two different points in time and the stability of the responses analyzed (in order to do this the survey must not be effected by time). The correlation coefficient value must be $r \geq 0.70$. This can be done for a group or an individual observer and the whole instrument can be tested (Litwin, 1995).

Alternate-form – This involves using different worded items (questions) to measure the same attribute. This is a method of getting around the practice effect, where respondent becomes familiar with the instrument and can respond with the answer they gave the last time.

Internal consistency reliability – This is applied to groups of items that measure different aspects of the same concept, not single items. It is a measure of how well the different items measure the same issue (Cronbach's Alpha) (Litwin, 1995).

The goal is to measure concepts in a way that helps us understand the world around us. As the survey is cross-sectional Test-retest can not be used, also, alternate-form requires the addition of repeat question which in this case would make the survey too long. Thus, reliability will be checked using pre-test and pilot studies and internal consistency.

3.5.2.1.2 Validity

According to Litwin (1995) validity is:

'The measure of how well the survey measures what it sets out to measure'.

Litwin (1995) explains that there are two types of validity, internal and external. External validity is concerned with how well the sample population findings apply to the entire population (generalization) and the ability of research to relate to a person's experience i.e. can they connect to it (transferability).

Internal validity is concerned with how well the study was carried out i.e. the study's design, what was and was not measured and how well it was measured. There are four types of internal validity (Litwin, 1995).

Face Validity – It is a review of items by untrained judges. It is the least scientific and considered worthless by some (Babbie, 1990; Litwin, 1995).

Content Validity – If a survey was conducted on mathematical skill and only asked about addition, the content of that survey would not be valid. This content is reviewed by people with knowledge of the research topic resulting in the identification of gaps in content.

Criterion Validity – The comparison of one instrument against another which has proven to be valid. Can be broken into two components, concurrent (measure of a variable against a gold standard) and predictive (the ability of a survey to forecast future events).

Construct Validity – This is the measure of how good a scale or survey instrument is in practical use and is based on years of experience with a survey instrument.

It is of two types, Convergent Validity and Divergent Validity.

Validity will be checked for by using content validity – using the pre-testing concept.

3.5.3 Statistical Tools

The various statistical tools used in the analysis of data are discussed in this section.

The convergent and discriminant validities of the constructs and their measures have been carried out.

Firstly, in the analysis of questionnaire, the status of all the issues under each component (input and output parameters) of tactical upgradation of the manufacturing sector has been assessed. The *Percent Points Score (P.P.S)* for each set of questions which reflect different issues under each component has been calculated. These measures reflect as to how well the area (issue) represented by that question is being looked in the industry.

Secondly, the status of manufacturing units in different key factors has been evaluated and the manufacturing units have been classified in to different categories. The score of each unit (in terms of Percent Points Score, PPS) in individual components has been calculated from the raw score of issues under each component. The criterion reported in earlier research studies has been used to classify the industries into different categories (Nanda and Singh, 2009).

Cronbach's Alpha Coefficient: This parameter is used for convergent validity. Convergent validity assesses the degree to which measures of the same concept (construct) are correlated. It is assessed by the correlation among items which make up the scale or instrument measuring the construct (internal consistency validity). The internal reliability of items (inter-item analysis) under each output parameter has been assessed by using Cronbach's alpha coefficient, as recommended for empirical research in operations management. Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the 'underlying construct'. Construct is the hypothetical variable that is being measured. Alpha coefficient ranges in value from 0 to 1 and may be used to describe the reliability of factors extracted from dichotomous (that is, questions with two possible answers) and/or multi-point formatted questions or scales. The higher the score, the more reliable the generated scale is (Best and Kahn, 1986; Flynn *et al.,* 1990; Radhakrishna, 2007). Cronbach's alpha coefficient (α) is defined as per the following equations.

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma^2_{Y_i}}{\sigma^2_X}\right)$$ ---------------- Equation 3.1

Here, N is the number of components (items or testlets), $\boldsymbol{\sigma^2_X}$ is the variance of the observed total test scores, and $\boldsymbol{\sigma^2_Y}$ is the variance of component *i*.

Alternatively, the standardized Cronbach's alpha can be defined as

$$\alpha = \frac{N \cdot \bar{c}}{(\bar{v} + (N-1) \cdot \bar{c})}$$ ---------------- Equation 3.2

Here, **N** is the number of components (items or testlets), $\bar{v}$ equals the average variance and $\bar{c}$ is the average of all covariances between the components.

t-Test Analysis: To find the relationship between key inputs and key outputs, Pearson's correlation coefficient values (r values) between various issues of inputs and the Development Indicators (output parameters) has been calculated. The correlation values obtained after this has been further validated using t-test. Pearson's correlation values and t-values (obtained from t-test) has been worked out to ascertain significant issues and factors contributing to the success of tactical upgradation program in industry. The t-values obtained (from t-test) can also be worked out through empirical expression indicated in Equation 3.3.

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \geq t_{n-2}$$ (from't' Tables) ---------------- Equation 3.3

Here, '***n*-2**' represents degrees of freedom (df) for a particular test, '**r**' represents Pearson's correlation coefficient between a particular input issue and an output parameter, '$\mathbf{t_{n-2}}$' is the $t_{critical}$ value from statistical't' tables for (**n–2**) degrees of freedom.

Regression Analysis: Further, step-wise linear regression analysis has been performed taking into account a set of all independent variables and each dependent variable individually. This technique can identify a set of variables which conjointly contribute significantly towards the criterion variable. The notations employed in this test include: β= Regression Coefficient (Beta Coefficient), R= Multiple Correlation Coefficient.

Principal Component Analysis: It is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is powerful tool for analyzing the data. The other main advantage of PCA is that once these patterns have been found in the data, the data can be compressed by reducing the number of dimensions, without much loss of information. The main objective of principal component analysis is to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variables.

3.5.4 Analysis of Survey

The analysis of questionnaire has been carried out from the following view points:

- To review the status of each factor influencing the technology capabilities of SMEs.
- To assess the overall standing of each manufacturing organization in various factors for tactical and technological development, leading to classification of organizations into various categories ranging from very good to very poor.
- To evaluate contributions of technology input factors towards achieving technology innovation of SMEs.

3.6 Evolving a Management Process

This phase of work presents a synthesis of learning's and outcomes of survey and case studies for their utilization through a qualitative model to evolve a technology innovation capability program for small scale industry of cutting tool region in Patiala.

The inferences drawn from the literature survey and survey results have been used to design a model for tactical development of SMEs in the region. Qualitative modeling has been used in this study which involves deriving expert opinion and using this along with findings of previous phases in structured manner. Four main techniques for modeling of the research problem have used in the present work. These include Options Field Methodology (OFM) and Options Profile Methodology (OPM) developed by Warfield (1979, 1982, 1990), Analytic Hierarchy Process (AHP) developed by Saaty (1980, 1986, 1990) and Fuzzy Set Theory (FST) methodology developed by Zadeh (1965).

A brief overview of the different techniques to be used for qualitative modeling of the research problem is presented as follows:

3.6.1 Options Field Methodology: Options Field Methodology (OPM) and Options Profile Methodology (OFM) provide a means for thorough development of the design situation and the design target description. The main steps in OFM are:

- *Construction of a Polystructure*: Generate a list of options as a solution to the present research problem using modified idea writing.
- *Initial Structuring*: Place the options into a set of categories.
- *Naming of Categories*: Develop a suitable name for each category.
- *Identification of Design Dimensions*: Identify the dimensions of the target.
- *Determining Clusters of dependent Dimensions*: Put various dimensions together into different clusters based on their proximity and affinity to each other.
- *Sequencing of Clusters*: Structure the clusters on the basis of sequence in which choices of options should be made.
- *Sequencing of Dimensions within Clusters*: Define the initial decision making sequence among dimensions of each cluster.
- *Displaying the completed Options Field*: Organize the Options Field displaying the clusters, dimensions and options in an orderly manner.

3.6.2 Options Profile Methodology: The next technique used in qualitative modeling is Options Profile Methodology (OPM). Here, various courses of actions (Profiles) of the design have been developed. These profiles can be employed to achieve overall objective of the research problem. The main steps in OPM are:

- Developing various courses of actions (Profiles) as a solution to the problem.
- Allocating various options to these alternate profiles.

The completed options profiles represent alternative approaches and courses of action to be adopted in each approach.

3.6.3 Analytic Hierarchy Process: The next step in modeling is use of Analytic Hierarchy Process (AHP) which involves the following steps:

- Deciding various sub-objectives (under the main objective) of the research problem. These are also referred to as ‘features of design’.
- Deciding the relative weightage of these sub-objectives using paired comparison by experts.

3.6.4 Fuzzy Set Theory: Finally, Fuzzy Set Theory (FST) technique will be employed. This approach quantifies (from the qualitative feedback provided by experts) the contribution of each profile towards each objective. The main steps in this approach are:

- Developing 'Position Matrices' to quantify the contribution of each profile to each objective.
- Making 'Weighted Position Matrices' to ascertain the effectiveness of each profile for the fulfillment of goals.
- Making 'Dominance Matrices' to find out the best course of action (profile) under optimistic, pessimistic and realistic scenario.

Finally, a conceptual framework will be developed which represents the linkage between essential components of 'Technology Innovation Capability Program' and elaborates on their relative contribution in meeting the overall research objective. The framework is based on outcomes of various phases of work including literature review, sample based survey, case studies and qualitative modeling.

3.7 Concluding Remarks

The methodology adopted for the study along with the step-by-step approach employed for the research has been elaborated in this chapter. Empirical studies will be used to yield rich data for statistical analysis. The learning issues from the literature review and results of questionnaire based survey will be synthesized to develop a systematic plan for technological innovation capability of small and medium enterprises.

CHAPTER - IV

SURVEY BASED RESEARCH RESULTS

4.1 Introduction

This chapter presents the analysis and major findings of survey based research data. The survey explores the status of technology innovation capabilities of cutting tool industry in the region.

4.2 Survey Methodology

For conducting the survey, the questionnaire based technique has been used. A relevant and comprehensive questionnaire has been utilized to seek information on various aspects of technology innovation capability through in-house research in small scale manufacturing industry.

For survey, the first task has been to design a questionnaire which seeks information on the status of technology innovation capability and its various components in the engineering industry. A simple, relevant and comprehensive questionnaire covering various aspects of the research problem has been specially designed. For effectively conducting the survey, the 'TIC Questionnaire' has been designed through an extensive literature review and validated through peer review from academicians and practitioners from industry. To ensure the relevance and effectiveness of questions to the manufacturing industry, the questionnaire has been pre-tested on a representative sample of industry. The feedback received has been incorporated to make the questionnaire more relevant for the purpose.

While designing the questionnaire, time constraints for people in the industry and the actual form in which information is available with the industry has been taken into consideration.

The present work considers three key areas (input) for overall assessment of technology innovation capabilities of cutting tool sector. These include

- Investment Capability
- Production Capability
- Linkage Capability

4.2.1 Industrial Units Surveyed

Small scale cutting tool manufacturing organizations in Patiala (Punjab, India) have been included in the survey. The main products of cutting tool industry in the region include metal slitting saws, slotting cutters, side and face cutters, shank type milling cutters, reamers, gear hobs, milling cutters, broaches, harvester blades, jack plane blades etc.

A total of 55 cutting tool units were selected from the list of registered units provided by the office of District Industrial Centre, Patiala. Around 55 questionnaires were distributed among these industries by making personal visits to the industrial units and having discussions with proprietors and senior executives. A total of 25 completed and usable questionnaire were received.

4.3 Analysis of Questionnaire

The analysis of questionnaire has been carried out to assess the main factors affecting performance of cutting tool manufacturing industry in the region. The status of each component (aspect) of Technology Innovation Capability program (TIC Program) in the industrial sector has been assessed. The industrial units have been classified on the basis of TIC components. The contributions of TIC initiatives in achieving Manufacturing Performance Improvements (Development Indicators) have also been evaluated.

4.4 Status of components of Technology Innovation Capability Program

The present work considers four key areas (components) for overall assessment of technology innovation capability initiatives in small scale sector. These include

- *Investment Capability*
- *Production Capability*
- *Linkage Capability*
- *Output Performance Parameters*

This section assesses the status of each of these components in the cutting tool sector in the region.

Table 4.1 presents the status of 'Investment Capability' component. A set of questions which reflect different issues under this component are presented in Table 4.1. For each question, the central tendency (C.T) and percent points scored (P.P.S) has been calculated. These measures reflect as to how well the area (issue) represented by a question is being looked after in the industry. Finally, the overall average for each component is calculated (considering all the issues under the component), which represents the status of the entire component. The overall average of 'Investment Capability' factor is 2.40 on a scale of 5.00.

Similarly, Table 4.2, Table 4.3, and Table 4.4 represent the status of 'Production Capability', 'Linkage Capability' and 'Output Performance Parameters' components of technology innovation capability (TIC) respectively.

4.4.1 Status of Investment Capability

This section discusses the status of *'Investment Capability'* issues in the manufacturing sector. The questions in the questionnaire for this component aim at collecting information on the following:

i) Purchasing of tangible technology, such as machinery and equipment.

ii) Purchasing intangible technology, such as patents and licences.

iii) In-house R&D presents the status of availability of resources for in-house research initiatives.

This section presents the status of each of these components (or aspects) in the manufacturing sector.

The response to individual questions (issues) on this component is presented in Table 4.1.

Table 4.1 shows the scores of different factors, signifying their relative impact in investment capability of manufacturing organizations. The scores are expressed in terms of 'Percent Point Score' (PPS). It is defined as the ratio of score obtained in an aspect to the maximum score possible in that aspect, expressed as a percentage.

Small scale sector in the region is doing fairly well (PPS= 77.6) with regards to investment in tangible assets, indicating that most of the organization (72%) have increased their investment in purchasing the tangible assets to maintain the state of art technology at a large extent only. A very few of the units (28%) have increased their investment to a moderate extent.

Effective utilization of resources by an organization results in benefits by providing the customer order of the product at the right time with a better quality. The manufacturing units have shown a relatively good response (PPS=72.00) in effective utilization of resources. Most of the units (56%) make use of resources to a large extent. A large number of units (44%) make use of resource to a moderate extent only.

Availability of good production technology is an important indicator of investment capability of the organization. The organizations surveyed show a only a moderate rating (PPS=59.20) in this issue. Most of the units do not have a state of the art production technology. There are only a very few units (12%) which to a large extent use latest production machinery, tooling and equipment.

Table 4.1 Evaluation of Investment Capability Issues

S.No.	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5 * N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	2 (W_2)	3 (W_3)	4 (W_4)	5 (W_5)			
1	Investment in tangible assets	25	0	0	7	14	4	97	**77.60**	3.88
2	Effective utilization of resources	25	0	0	11	13	1	90	**72.00**	3.60
3	Availability of better production technology	25	0	4	18	3	0	74	**59.20**	2.96
4	Investment in intangible assets	25	4	19	1	1	0	49	**39.20**	1.96
5	Use of intellectual property as a strategic tool	25	20	4	1	0	0	31	**24.80**	1.24
6	Employee training	25	1	0	17	6	1	81	**64.80**	3.24
7	Use of tactical knowledge	25	0	5	14	6	0	76	**60.80**	3.04
8	Earmarking of funds for R&D	25	22	0	2	1	0	32	**25.60**	1.28
9	Research and innovation initiatives for process improvements	25	9	15	1	0	0	42	**33.60**	1.68
10	Use of R&D initiatives for development	25	1	14	7	2	1	63	**50.40**	2.52
11	Investment in R&D as a proportion of turnover	25	24	1	0	0	0	26	**20.80**	1.04
									Overall Average (On a scale of 5.00)	**2.40**

^ **Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+5\times W_5$**

Investment in intangible assets is an important factor explaining the investment capability of innovation based organizations. However, the small units in the region have shown a relatively poor response (PPS=39.20) to the investment in intangible assets. Most of the units (76%) make investment in intangible assets only to a small extent. There are 16% units which do not make any investment in intangible assets. Further, the small units which are not making investment in intangible assets are also unaware about the use of intellectual property rights as a strategic tool. The manufacturing units have shown a relatively very poor response (PPS=24.80) with regards to this issue. Most of the units (80%) have never applied for a patent or obtained it.

Literature reveals that innovative organizations rely heavily on proper training of employees to enhance creativity their innovation skills. The manufacturing units have shown a moderate score (PPS=64.80) in this issue. Most of the units (68%) provide training, either during orientation period through senior executives or on-the-job training where employees learn through experience. Surprisingly, none of the organizations make use of standard creativity tests to improve innovation level of employees. Also, there is no encouragement to participate in conferences, workshops, seminars etc.

The cutting tool industry has shown a moderate rating (PPS=60.80) with regards to tactical knowledge. In most of the organizations (80%), the entrepreneurs exploit and capitalize on this unspoken and tatic knowledge only to a small or moderate extent.

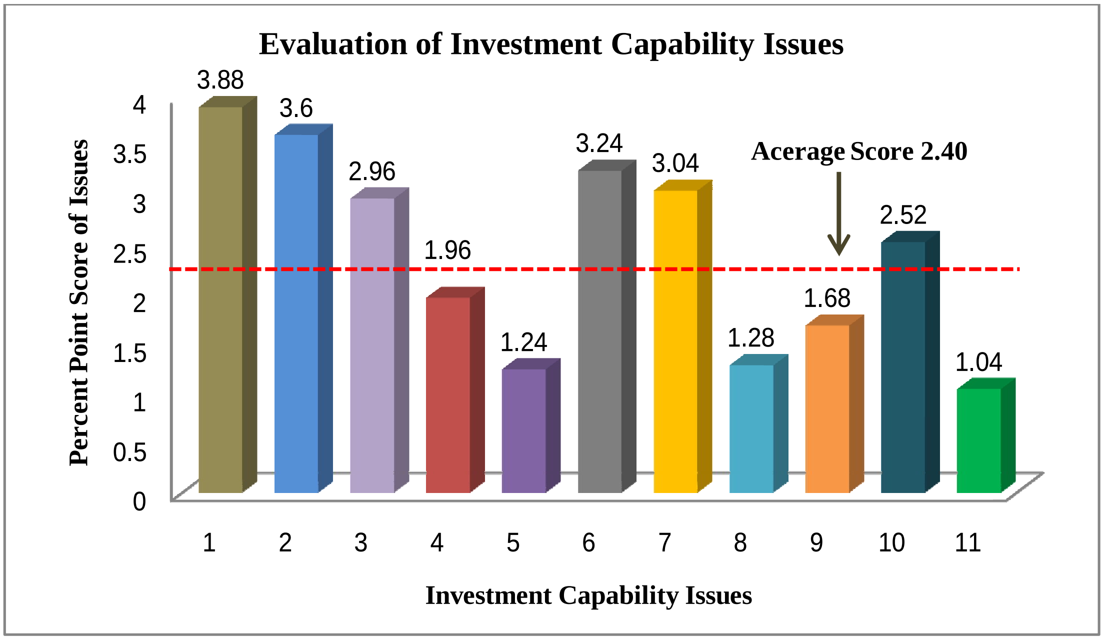

Figure 4.1 Performance regarding Investment Capability Issues

The state of affairs in the industry is disappointing (PPS= 25.60) as far as earmarking of funds specifically for research activities is concerned. Most of the units (88%) do not clearly allocate funds for research and development initiatives. A few units (08%) club these funds with other developmental activities. There are only a very few organizations (2%) where management clearly assigns funds for research projects aimed at innovations for new product and process developments.

Research and innovation initiatives for process improvements are necessary for an organization. The cutting tool sector has shown a very poor rating (PPS=33.60) with regards to this issue. Most of the units (96%) use such initiatives for process improvement only to a small extent.

The condition of small scale units with regards to investment in R&D is very poor (PPS=20.80). A large number of units (96%) do not earmark any investment for R&D related activities.

The average score of this aspect is 2.40 (out of 5.00) as shown in Figure 4.1. The survival of industry is not feasible in the absence of research and development initiatives and for that infrastructure and financial support are needed. The critical analysis of various issues related to 'Investment Capability' component reveals that most of the issues and concerns of this component have shown very low rating. Substantial improvements need to be affected in following issues- increasing investment in intangible assets, use of intellectual property as a strategic tool, research and innovation initiatives for process improvements and earmarking separate budget for R&D activities.

4.4.2 Status of Production Capability

This section discusses the status of '*Production Capability*' issues in terms of quality management in the manufacturing sector.

Management leadership fosters change in an organization through continuous improvement and open communication and this potentially explains the improvement in financial performance, customer service and product quality (Nair, 2006).The manufacturing organizations surveyed have shown a moderate rating (PPS=67.20) in leadership factor. Many of the units (60%) showed that senior managers actively encourage change and implement a culture of trust, involvement and commitment in moving towards 'Best Practice' to a marginally extent and few of the units (44%) are extremely good in using tactical knowledge for innovation and improvements.

The literature has recognized the importance of human aspects (e.g. training, compensation schemes) in a quality management context (Bowen and Lawler, 1992). Such idea is suggested by evaluation and academic models incorporating human practices, which indicate that effective human resources are necessary for the development of quality management. For this purpose, the employees need training; this will allow them to identify and solve problems, to improve work methods, and to take responsibility for quality. This training must include technical and human aspects such as problem solving, data analysis and statistical techniques (Ishikawa, 1985). Then, in order to improve quality, employees can be trained in the use of quality techniques and tools (Nair, 2006). Such training will generate an increased awareness of quality-related issues and can facilitate a continuous process of learning (Tari *et al.*, 2007).The manufacturing organizations in the region have obtained an average rating (PPS=61.60) in this issue. Most of the units (76%) have been found moderately focus on human resource management.

The response to individual questions (issues) on this component is presented in Table 4.2

Table 4.2 Evaluation of Production Capability Issues

S. No.	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	2 (W_2)	3 (W_3)	4 (W_4)	5 (W_5)			
1	Top management leadership	25	0	1	15	8	1	84	**67.20**	3.36
2	Human resource management	25	0	2	19	4	0	77	**61.60**	3.08
3	Process management	25	0	8	15	2	0	69	**55.20**	2.76
4	Customer focus	25	0	0	12	12	1	89	**71.20**	3.56
5	Quality planning activities	25	0	17	7	1	0	59	**47.20**	2.36
6	Organization structure	25	0	10	12	2	1	69	**55.20**	2.76
7	Process and quality improvement programs	25	10	14	0	1	0	42	**33.60**	1.68
8	Use of quality tools on shop floor	25	7	17	0	1	0	45	**36.00**	1.80
9	Policies & procedures for quality control system	25	0	15	8	2	0	62	**49.60**	2.48
									Overall Average (On a scale of 5.00)	**2.64**

^ Total Point Score (TPS) = $1 \times W_1 + 2 \times W_2 + 3 \times W_3 + 4 \times W_4 + 5 \times W_5$

Process management helps to ensure that variation is kept within acceptable bounds; in turn, efforts aimed at managing and continually reducing process variation leads to continuous quality improvement (Tari *et al.*, 2007). The small scale sector is showing a relatively poor rating (PPS=55.20) with regards to this issue. Most of the units (92%) focus on process management issues only moderately or to a small extent.

Customer focus is a very important indicator in quality management. Customer focus relates to an organization's commitment to determine and meet current and emerging customer requirements and expectations, to provide effective customer relationship management and to ensure customer satisfaction (Samson and Terziovski, 1999; Das *et al.*, 2000). It can be reasoned that investments in customer complaints evaluation and expectation monitoring systems enable better design of products and processes, thereby improving product quality and operational performance (Nair, 2006). The small scale sector shows a relatively good rating (PPS=71.20) in terms of customer focus. A large number of organizations (48%) have been found to be good to a large extent in this issue.

Quality planning affects human resource management and process management. Since a firm must plan its activities to improve quality, it seems logical that effective planning should positively affect process management and improvement. Since a firm must plan its activities to improve quality, it seems logical that effective planning should positively affect process management and improvement. (Tari et al., 2007). The cutting tool units have show poor rating (PPS=47.20) with regards to this issue. Most of the organizations (68%) lack in quality planning at their units. The remaining units focus on these issues only moderately or to a small extent.

Organization structure is the formal structure of task and reporting relationships that controls, coordinates, and motivates employees so that they cooperate to achieve an organization's goals. Organization structure also show poor rating (PPS=55.20). Most of the organizations (48%) focus on their organization structure to a moderate extent. Few of the units (40%) focus on this issue to a small extent.

Process and quality improvement programs involve frontline employees who interact directly with customers or products the customers purchase in the activities to improve processes and quality. Process and quality improvement program is indicated by very poor status (PPS=33.60) of the manufacturing organization. Most of the organizations (56%) have obtained benefits from the process and quality improvement program to a small extent only. Few of the units (40%) do not obtain benefits at all.

Use of the quality tools (such as Pareto Charts, Ishikawa Diagrams, Control Charts, Fault Tree Analysis etc.) on shop floor is an important indicator of production capability. Small units have obtained a very poor score (PPS=36.00) in this issue. Most of the organizations (68%) use quality tools only to a small extent on the shop floor. About one third of the units (28%) do not use these tools at all, which is discouraging.

Policies and procedures for quality control system is also an important indicator in production capability in terms of quality management. The cutting tool units have shown a poor rating (PPS=49.60) with regards to this issue. Most of the units (60%) have framed and implemented these policies to a small extent only.

The overall score of this aspect is 2.65 (out of 5.00) as depicted in Figure 4.2. The analysis reveals that some issues need critical attention such as implementing policies and procedure for quality control system, use of quality tools on the shop floor, process and quality improvement programs and quality planning etc.

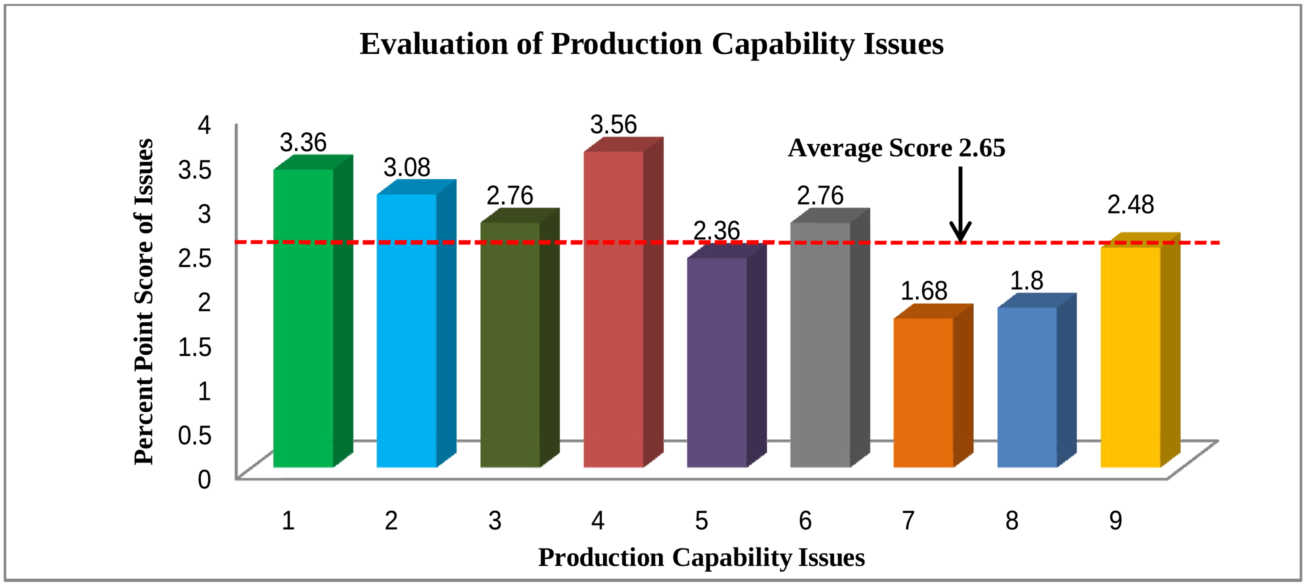

Figure 4.2 Performance regarding Production Capability Issues

4.4.3 Status of Linkage Capability

This section presents the status of the linkage capability aspect of manufacturing organizations with other small units, large enterprises and academia etc.

The keys and statements on linkage capability aim at collecting information on the following:

i) Product and production related assistance through collaboration with small units and large enterprises, benefits obtained through subcontracting.

ii) Industry–Institute collaborations on research and development for solving technology related problems.

iii) Cooperative and contract based research with universities, university labs and infrastructure for testing and inspection, combined supervision of thesis etc.

The response to various issues on this component is presented in Table 4.3.

Manufacturing organizations are feeling the pressure of shifting markets because of globalization and have to operate in a very competitive environment. Their need for support and information is high and they must make improvements in internal strategies to start interacting with external organizations. In an environment of increasing turbulence and uncertainty, manufacturing enterprises must rely on developing new products and new markets to achieve growth, which requires them to establish or join networks of collaboration with various business partners (Fabi et al., 2009).

The survey results show a very poor rating (PPS=37.00) for industry-industry collaboration with positive results. Most of the units (60%) have obtained only to a small extent any positive results through these collaborations. Nearly one third of the units do not receive any positive result through collaboration. Industries need to work together towards a common goal by sharing information and resources in order to undertake joint projects. Firms' collaboration with external organizations allows the expansion of their range of expertise and can support the development of new products.

Table 4.3 Evaluation of Linkage Capability Issues

S. No.	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	2 (W_2)	3 (W_3)	4 (W_4)	5 (W_5)			
1	Industry-industry alliance with positive results	25	7	15	2	1	0	47	**37.60**	1.88
2	Subcontracting benefits with large enterprises	25	9	14	2	0	0	43	**34.40**	1.72
3	Cooperative research with institutes for joint R&D projects	25	13	12	0	0	0	37	**29.60**	1.48
4	Contract based research with institutes	25	10	15	0	0	0	40	**32.00**	1.60
5	Industry-academia alliance with positive results	25	11	14	0	0	0	39	**31.20**	1.56
6	Technology transfer from academia to industry	25	25	0	0	0	0	25	**20.00**	1.00
7	University labs for testing and inspection	25	4	9	11	0	1	60	**48.00**	2.40
8	Expert lectures and training programmes by academicians	25	8	14	3	0	0	45	**36.00**	1.80
9	Combined supervision of thesis	25	20	5	0	0	0	30	**24.00**	1.20
Overall Average (On a scale of 5.00)										**1.63**
^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+5\times W_5$										

In subcontracting relationship, subcontractors (SMEs) deliver product or service to the contractors (LEs) as specified by the latter for their production requirements. Subcontracting firms receive assistance from the contractor and the degree of inter- firm linkages between the participating firms has to be assessed in terms of the assistance provided by the contractor to the subcontractor. Small scale industrial sector has failed (PPS=34.40) in terms of forging subcontracting relations with large enterprises and obtaining benefits through such collaborations. A little more than half of the units have received benefits only to a very small extent. However, the remaining small scale manufacturing units either have not received any benefit through this collaboration or do not have subcontracting relationships with any large enterprise.

In cooperative research and development – all activities related to the evolution of new products and services inclined to work together with another or others for a common purpose. Small scale sector with an extremely low rating (PPS=29.60) in this issue fails to notice this fact. Nearly half of the units are not involved in any type of cooperative research with universities.

Contract based research with universities is not involved in 40% of the small scale manufacturing units and thus a very low (PPS= 32.00) rating in this issue has been shown. Most of the units (60%) are involved only to a small extent in this type of collaboration.

Small scale manufacturing units are not interacting much with universities and external research institutes for technology development. Manufacturing organization have shown an unreasonably low rating, in terms of percent points scored in this issue (PPS= 31.20 only). A nearly more than half of the units obtain positive results to a small extent only through collaboration and a nearly less than half of the units either do not collaborate with academic institutes or do not obtain positive results through collaboration. Firms and universities need to apply thinking strategies to their surroundings, to increase collaborations and knowledge sharing while ensuring that sufficient mutual benefits can be derived. By collaborating with universities, firms may reduce uncertainty inherent from the innovation process, as well as expand their markets, increase access to new or complementary resources, keep up with evolution of scientific knowledge, and create new technological learning options on future technologies.

The status of technology transfer from academia to industry in the region also show an extremely poor rating (PPS=20.00) indicating that there is no technology transfer from academia to industry in the region.

Nearly one fifth of the industrial units are not able to take benefits from the University labs for testing and inspection and thus a very poor rating (PPS= 48.00) is shown. A few units (36%) consider it to use lab facilities at technical institutes only to a small extent.

External research institutes and universities can help the small scale manufacturing units in product innovation efforts through expert lectures on upcoming key technologies. Nearly one tenth believe that this issue can be of help to a moderate extent. More than half (56%) of the units have rarely benefited from this issue to a small extent. The remaining one third organizations do not consider this activity to be of much use.

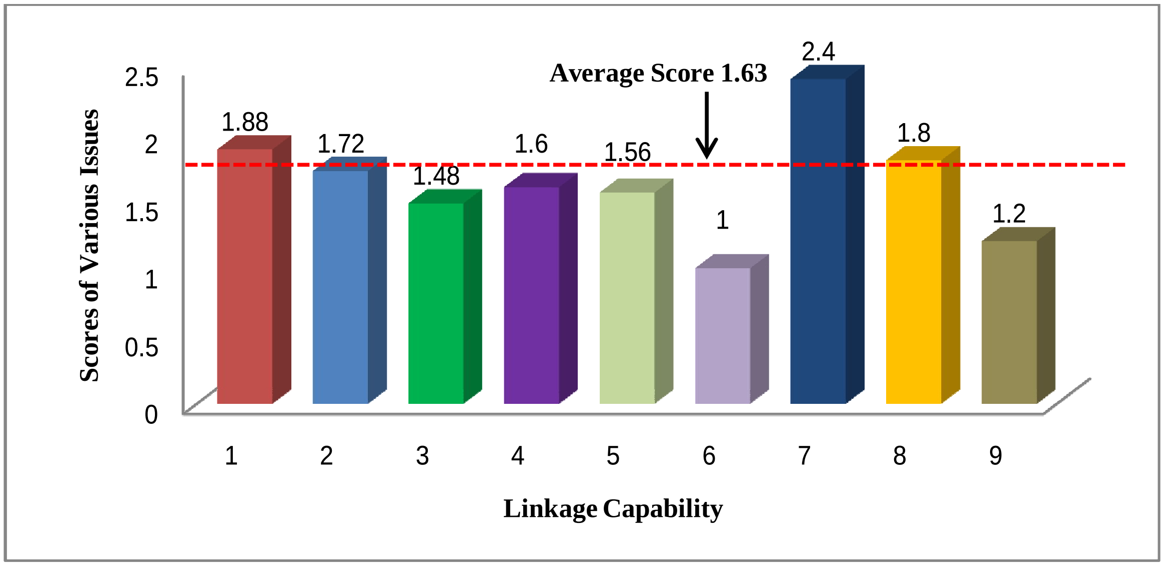

Figure 4.3 Performance regarding Linkage Capability Issues

A large fraction (80%) of the units is not involved in collective guidance of thesis with universities and thus an extremely poor rating (PPS= 24.00) in this issue has been shown.

The overall score of this aspect is 1.65 (out of 5.00) as depicted in Figure 4.3. Majority of the industries have acquired technology from large Indian industries rather than developing technology through interaction mode. The performance of industry in developing technology through collaborations with academic institutes or research institutes is also below desired levels.

4.5 Status and Classification of Units in various TIC components

The objective of this part of analysis is to evaluate the status of manufacturing units in different components of Technology Innovation Capability (TIC) program and to classify the units into different categories. The score of each unit (in terms of Percent Point Score, PPS) in individual components of '*Investment Capability*, '*Production Capability*', and '*Linkage Capability*' has been calculated from the raw score of issues under each component.

While deciding upon the choice carrying highest marks in each issue, the levels achievable by small scale manufacturing industry in India have been taken into consideration. Requirements for highest score are definitely less than those for large enterprises or small units in developed nations. Thus, a score close to 100% (PPS≈100.00) obtained by an organization has been graded as *Very Good* only and not *Excellent*. Further, the organizations score just 20% marks (PPS= 20.00) in a component if all responses to various issues of that component fall at the lowest choice and score 100% marks if all responses correspond to the best choice. The criterion used to classify the industries into different categories is presented in Table 4.4. Table 4.5 presents the performance rating of industrial units in various components of technology development.

Table 4.4 Criteria for Classification of Industries

Range of Percent Score	Inference	Category
25-35	Industry at the lowest stage. Nearly all responses to the lowest choice box on an average.	Very Poor
36-55	Industry at a poor stage. Nearly all responses to the third or fourth choice on an average.	Poor
56-75	Nearly all responses to the second or third stage on an average.	Fair
76-90	Industry at a good stage. Nearly all responses to the first and second choice on an average.	Good
91-100	Industry at a highest stage. Nearly all responses to the highest choice on an average.	Very Good

(Nanda and Singh, 2009b)

Table 4.5 Performance Rating of Units in Various Input Components of TIC Program

Range of PPS → / Aspect ↓	20-25	25-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
	Number of Units in a given PPS Range															
Investment Capability	0	0	0	2	6	10	5	1	0	0	1	0	0	0	0	0
Production Capability	0	0	0	1	4	5	5	8	1	0	0	1	0	0	0	0
Linkage Capability	4	5	5	8	3	0	0	0	0	0	0	0	0	0	0	0

The industry wise performance in ‘*Investment Capability’* component is presented in Figure 4.4. The classification of units in this component is presented in Figure 4.5.

The performance of organizations in ‘*Investment Capability*’ component is moderate only with an average score of 48.07 %. More than 92% of the units fall in ‘*Poor*’ category in this component which is discouraging. Only 8% units are at a ‘*Fair*’ level.

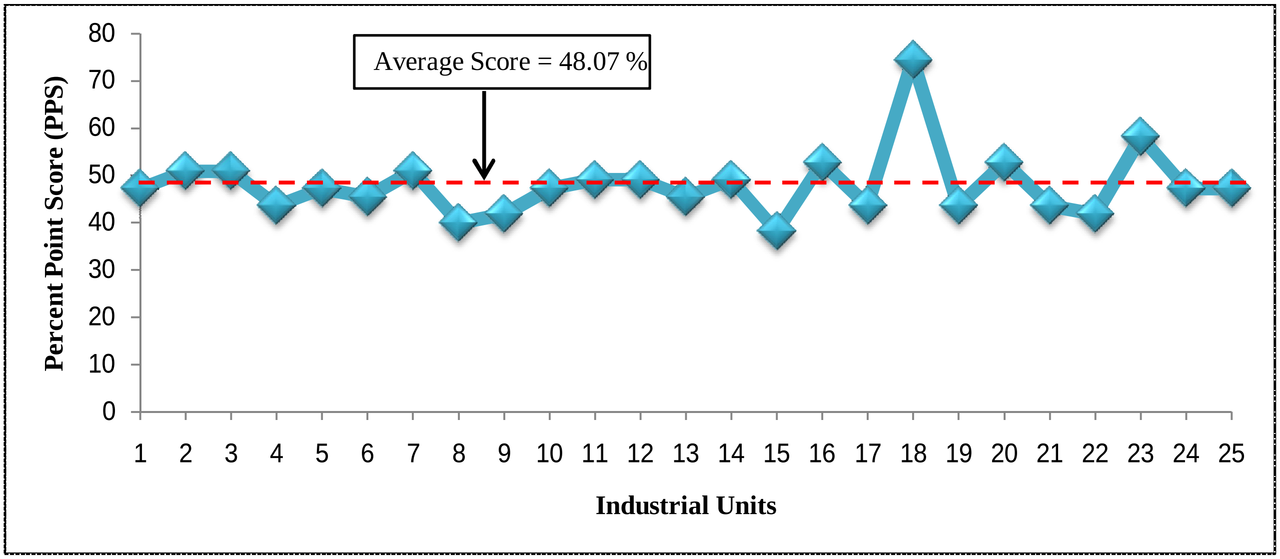

Figure 4.4 Performance of Units in Investment Capability Component

Percent Point Score (PPS)	Category	Number of Units in the Range	Proportion of Units in the Range (%)
20-35	Very Poor	-	-
36-55	Poor	23	**92**
56-75	Fair	2	**8**
76-90	Good	-	-
91-100	Very Good	-	-

Figure 4.5 Classification of Units in Investment Capability Component

The manufacturing units can improve performance in this component if management pays proper attention to investment in tangible technology and makes adequate investments both in formal training as well as in-house training of employees.

The performance and classification of units in '*Production Capability*' component is depicted in Figure 4.6 and Figure 4.7 respectively.

The average score of organizations in '*Production Capability*' component is 52.90%. Only 4% of the units are at 'Good' level. More than half of the units (60%) are at a 'Poor' level and about one third of the units are at 'Fair' level.

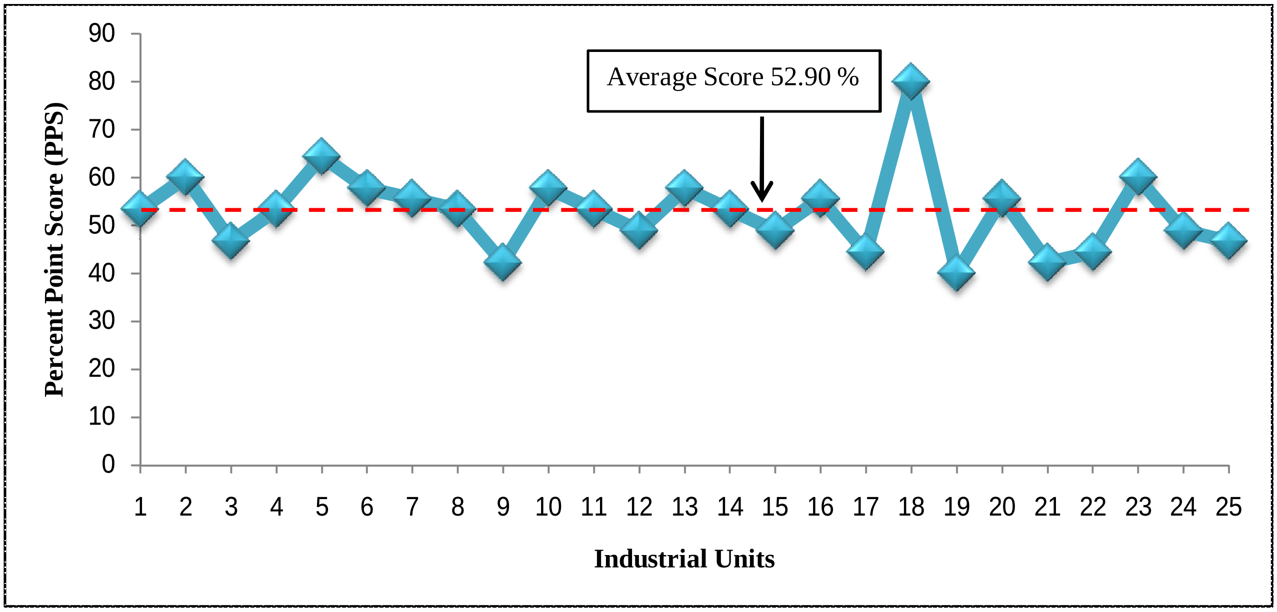

Figure 4.6 Performance of Units in Production Capability Component

Percent Point Score (PPS)	Category	Number of Units in the Range	Proportion of Units in the Range (%)
20-35	Very Poor	-	-
36-55	Poor	15	**60**
56-75	Fair	9	**36**
76-90	Good	1	**4**
91-100	Very Good	-	-

Figure 4.7 Classification of Units in Production Capability Component

The manufacturing units can improve performance in this component if management pays proper attention to use of quality tools on shop floor, quality planning activities, and process and quality improvement programs.

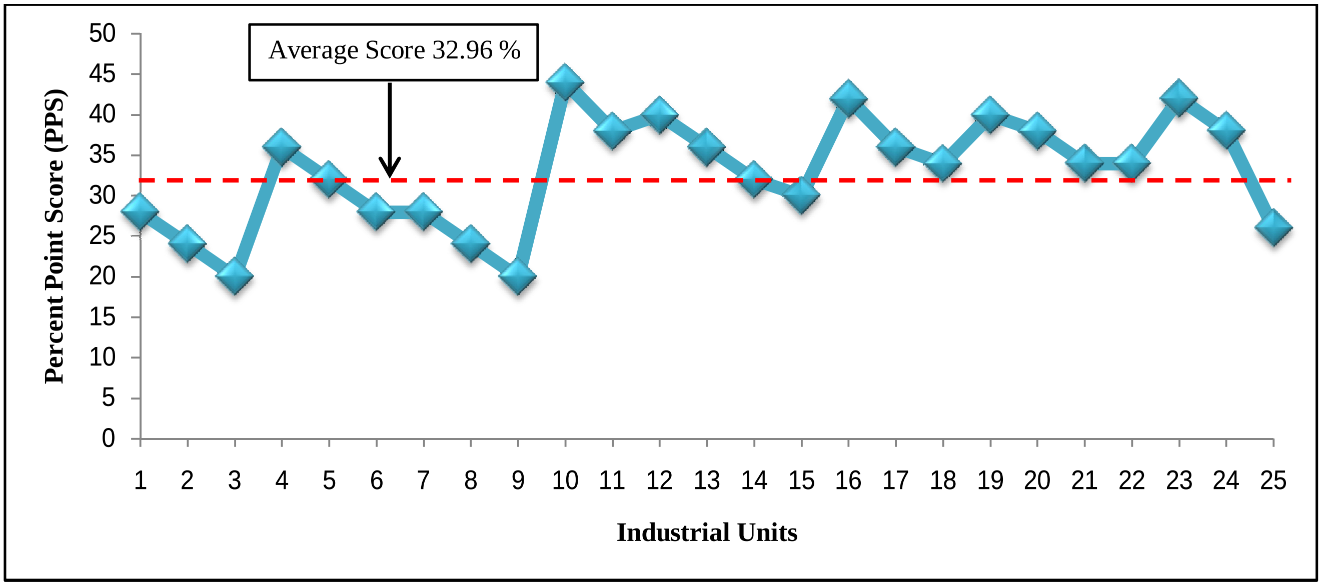

Figure 4.8 Performance of Units in Linkage Capability Component

Percent Point Score (PPS)	Category	Number of Units in the Range	Proportion of Units in the Range (%)
20-35	Very Poor	14	**56**
36-55	Poor	11	**44**
56-75	Fair	-	-
76-90	Good	-	-
91-100	Very Good	-	-

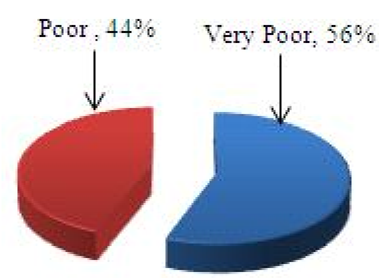

Figure 4.9 Classification of Units in Linkage Capability Component

The performance and classification of units in '*Linkage Capability*' component is depicted in Figure 4.8 and Figure 4.9 respectively.

The performance of organizations in '*Linkage Capability*' component is far below satisfactory with an average score of 32.96 %. None of the units fall even in 'Fair' category. About 56 % of the units fall in '*Poor*' category in this component. 44 % units are at a '*Very Poor*' level.

The manufacturing units need to penetrate into new markets to increase their market share and sales. The quality of the products needs to be improved and cost be reduced to retain existing customers and increase profit margins.

4.6 Principal Component Analysis

Principal Component Analysis (PCA) has been performed with all the input and output research constructs considered in the present research problem. The aim has been to identify the attributes which emerge as most relevant in defining the variable. The components are extracted based on eigen value greater than 1 to reduce the dimensionality of the variables.

In '*Investment Capability*' input factor, three components have been extracted based on eigen value greater than 1 (although there were four components having eigen value greater than 1).

Table 4.6 Principal Component Analysis of Investment Capability Issues

Components	Eigen Value	Percentage of Variance	Cumulative Percentage
1	**4.13**	37.59	37.59
2	**2.17**	19.80	57.39
3	**1.23**	11.24	68.64
4	1.07	9.76	78.40
5	0.60	5.48	83.89
6	0.54	4.92	88.82
7	0.43	3.97	92.79
8	0.34	3.17	95.97
9	0.21	1.90	97.88
10	0.15	1.38	99.26
11	0.08	0.73	100.00

Table 4.7 Rotated Component Matrix of Investment Capability Issues

Issues under Investment Capability	Component		
	1	**2**	**3**
• Investment in tangible assets	-0.03	-0.27	**0.81**
• Effective utilization of resources	-0.10	0.20	**0.77**
• Availability of better production technology	0.22	0.27	**0.78**
• Investment in intangible assets	**0.89**	0.14	0.10
• Use of intellectual property as a strategic tool	**0.84**	0.19	-0.11
• Employee training	-0.14	0.36	0.03
• Use of tactical knowledge	0.37	-0.12	0.27
• Earmarking of funds for R&D	0.49	**0.74**	-0.00
• Research and innovation initiatives for process improvements	0.27	**0.55**	0.37
• Use of R&D activities	0.16	0.87	0.04
• Investment in R&D as a proportion of annual turnover.	**0.73**	0.51	0.15

The first component, in particular, explains most of the total variance (percentage variance= 37.59%), and related items have high loads on the component itself, highlighting their relative importance. The items that should be combined in the first component are investment in intangible assets, use of intellectual property as a strategic tool and investment in R&D.

The second component (percentage variance = 19.80%) emphasizes on issues related to earmarking of funds for R&D and the research and innovation initiatives for process improvements. The third component (percentage variance = 11.24%) can be interpreted to be comprising of investment in tangible assets, effective utilization of resources and availability of better production technology.

Table 4.8 Principal Component Analysis of Production Capability Issues

Components	Eigen Value	Percentage of Variance	Cumulative Percentage
1	**4.21**	46.82	46.82
2	**1.12**	12.49	59.31
3	**1.06**	11.82	71.13
4	0.93	10.42	81.56
5	0.62	6.96	88.53
6	0.39	4.41	92.95
7	0.25	2.82	95.77
8	0.23	2.61	98.39
9	0.14	1.60	100.00

Table 4.9 Rotated Component Matrix of Production Capability Issues

Issues under Production Capability	Component		
	1	2	3
• Leadership	0.18	**0.53**	0.16
• Human resource management	-0.03	0.02	**0.85**
• Process Management	**0.83**	-0.02	0.05
• Customer Focus	0.41	0.19	**0.70**
• Planning	**0.64**	0.57	-0.05
• Organization structure	**0.58**	0.39	**0.55**
• Process and quality improvement program	-0.03	**0.90**	0.05
• Use of quality tools on shop floor	**0.84**	0.15	0.24
• Policies & procedures for quality control system	**0.58**	0.44	0.43

Further the analysis extracted three components among the nine items of '*Production Capability*' input parameter which explain 71.14% of the total variance. The first component, in particular, explains most of the total variance (percentage variance = 46.82%) and can be interpreted to consist of five main issues viz. process management, quality planning activities, organizational structure, use of quality tools on shop floor and policies and procedures for quality control. The second component comprises of top management leadership, and process and quality improvement programs.

The third component comprises of human resource management, customer focus, and organizational structure.

Table 4.10 Principal Component Analysis of Linkage Capability Issues

Components	Eigen Value	Percentage of Variance	Cumulative Percentage
1	**3.89**	43.27	43.27
2	**1.60**	17.78	61.05
3	**1.17**	13.03	74.09
4	0.89	9.91	84.00
5	0.54	6.07	90.08
6	0.42	4.70	94.78
7	0.19	2.18	96.96
8	0.15	1.71	98.68
9	0.11	1.31	100.00

Table 4.11 Rotated Component Matrix of Linkage Capability Issues

Issues under Linkage Capability	Component		
	1	2	3
• Industry-industry alliance with positive results	**0.87**	0.03	0.11
• Benefits through collaborations with small units	0.35	**0.74**	-0.44
• Subcontracting benefits with large enterprises	**0.88**	0.17	0.11
• Cooperative research with institutes for joint R&D projects	**0.87**	0.15	0.16
• Contract based research with institutes	0.23	0.03	**0.70**
• Industry-academia alliance with positive results	**0.65**	0.18	0.37
• University labs for testing and inspection	0.43	**0.71**	0.07
• Expert lectures and training programmes by academicians	0.16	0.07	**0.84**
• Combined supervision of thesis	-0.10	**0.81**	0.27

'*Linkage Capability*' factor can also be compressed to three components which explain 74.09% of the total variance. The first component (percentage variance = 43.27%) consists of industry-industry alliance with positive results, subcontracting benefits with large enterprises, cooperative research with institutes for R&D projects and industry-academia alliance with positive results. Benefits through collaborations with small units, university labs for testing and inspection and combined supervision of thesis are the items related to the second component. The third component (percentage variance = 13.04%) comprises of contract based research with institutes, and expert lectures & training programmes by academicians.

Table 4.12 Input and Output Parameters

Input Factors	Output Parameters
I1. Investment Capability	Z1. Innovation Performance
I2. Production Capability	Z2. Sales Performance
I3. Linkage Capability	Z3. Product Performance

Table 4.13 Issues regarding Input and Output Performance Parameters

Key Inputs	Key Outputs
I1. Investment Capability E1. Investment in tangible assets E2. Effective utilization of resources E3. Availability of better production technology E4. Investment in intangible assets E5. Use of intellectual property as a strategic tool E6. Employee training E7. Use of tactical knowledge E8. Earmarked funds for R&D E9. Research and innovation initiatives for process improvements E10. Use of R&D initiatives E11. Investment in R&D **I2. Production Capability** F1. Top management leadership F2. Human resource management F3. Process management F4. Customer focus F5. Quality planning activities F6. Organizational structure F7. Process and quality improvement programs F8. Use of quality tools on shop floor F9. Policies & procedures for quality control system **I3. Linkage Capability** L1. Industry-industry alliance with positive results L2. Benefits through collaborations with small units L3. Subcontracting benefits with large enterprises L4. Cooperative research with institutes for joint R&D projects L5. Contract based research with institutes L6. Industry-academia alliance with positive results L7. Technology transfer from academia to industry L8. University labs for testing and inspection L9. Expert lectures and training programmes by academicians L10. Combined supervision of thesis	**Z1. Innovation Performance** I1. Increase in product mix and product variants I2. Improvement in existing product features I3. Proportion of new products as a percentage of total products I4. Changes in response to market demands **Z2. Sales Performance** S1. Proportion of sales improvement due to new products S2. Increase in market share S3. Penetration into new markets S4. Increase in profit margins S5. Retention of existing customers/market S6. Improvement in sales **Z3.Product Performance** P1. Improvement in quality level P2. High cost/benefit ratio P3. Improvement in product life cycle P4. Improvement in technical characteristics of products P5. Lowering of cost of production

4.7 Contributions of TIC initiatives in achieving Performance Improvements

From the literature findings, three input factors (I1, I2, I3) and three output parameters (Z1, Z2, Z3) have been identified as significant in analyzing input of technological innovation capability related activities of organizations. These input and output parameters are presented in Table 4.12.

The detailed description of issues related to these parameters is listed in Table 4.13.

The internal reliability of items under each input and output parameter (inter-item analysis) has been assessed by using Cronbach’s alpha co-efficient, as recommended for empirical research in operations management (Flynn *et al.*, 1990).

Cronbach’s alpha values calculated for various categories are greater than 0.7, which is considered adequate for exploratory work. This also indicates high reliability of data collected through the ‘TIC Questionnaire’. Cronbach’s alpha values calculated for various input parameters are presented in Table 4.14.

Table 4.14 Cronbach’s Alpha values for all Key Parameters

Key Parameter		**Cronbach's Alpha Value**
Investment Capability	I1	0.781
Production Capability	I2	0.847
Linkage Capability	I3	0.794
Innovation Performance	Z1	0.708
Sales Performance	Z2	0.812
Product Performance	Z3	0.814

4.7.1 Association between Input and Output Performance Parameters

In this section, the contribution of each input factor towards each output factor has been evaluated. For this, Pearson’s correlation coefficient values (r values) between each input factor and the output parameters have been calculated. The correlation values obtained have been further validated using statistical tools like t-Test and multiple regression analysis.

Pearson’s correlations and significance levels (p-values) for pairs of interrelationships of various input and output factors are depicted in Table 4.15.

The t-values can also be worked out through the empirical expression provided in Equation 4.1.

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \geq t_{n-2} \text{ (from‘t’ Tables)} \qquad \text{---------------------- Equation 4.1}$$

where, '*n*-2' represents degrees of freedom (df) for a particular test, 'r' represents Pearson's correlation coefficient between a particular input and output parameter, t_{n-2} is the $t_{critical}$ value from statistical 't' tables corresponding to (n – 2) degrees of freedom.

4.7.2 Correlation Analysis

The correlation matrix depicting the association between independent and dependent variables has been established and presented in the Table 4.15.

The input parameter, '*Investment capability'* (I1) has shown a significant correlation with all the research output parameters. It shows a very significant association (r=0.629; p=0.001) with '*Innovation Performance*' (Z1); affects very significantly (r=0.771; p=0.000), the '*Sales Performance*' (Z2); and also contributes effectively (r=0.460; p=0.021) towards '*Product Performance*' (Z3). As a result, the '*Investment Capability'* (I1) parameter shows a very significant correlation (r=0.703; p=0.000) with '*Overall Research Output*' (Z).

Table 4.15 Association between Independent and Dependent Variables

DEPENDENT VARIABLES ➡ INDEPENDENT VARIABLES ⬇			Innovation Performance	Sales Performance	Product Performance	Overall Research Output
			Z1	**Z2**	**Z3**	**Z**
Investment Capability	**I1**	r	0.629**	0.771**	0.460*	0.703**
		t	3.880**	5.806**	2.484*	4.740**
		p	0.001	0.000	0.021	0.000
Production Capability	**I2**	r	0.697**	0.764**	0.573**	0.783**
		t	4.661**	5.678**	3.353**	6.036**
		p	0.000	0.000	0.002	0.000
Linkage Capability	**I3**	r	0.285	0.458*	0.269	0.379
		t	1.425	2.470*	1.339	1.964
		p	0.165	0.021	0.194	0.000

** Correlation significant at 0.05 level (2-tailed)* *** Correlation significant at 0.01 level (2-tailed)*

The input parameter, '*Production Capability*' (I2) has also shown a significant correlation towards all the research output parameters. It significantly contributes (r=0.697; p=0.000) towards '*Innovation Performance*' (Z1); very significantly affects (r=0.764; p=0.000) the '*Sales Performance*' (Z2); and also contributes effectively towards (r=0.573; p=0.002) '*Product*

Performance' (Z3). As a result, the '*Production Capability*' (I2) parameters shows a very significant correlation (r=0.783; p=0.000) with '*Overall Research Output*' (Z).

The input factor, '*Linkage Capability*' (I3) has not contributed very effectively towards the output parameters. This input factor has shown a significant association (r=0.458; p=0.021) only with the '*Sales Performance*' (Z2) output.

4.7.3 Multiple Regression Analysis

Table 4.16. shows the regression analysis with the dependent variable as '*Innovation Performance*' and the three input factors as independent variables. The results indicate that, '*Investment Capability*' and '*Production Capability*' together can predict 29.3% of the variance in '*Innovation Performance*' variable the other input variables will add little to the variance.

Table 4.17 shows the regression analysis with the dependent variable as '*Sales Performance*' and the three input factors as independent variables. The results indicate that, '*Investment Capability*' and '*Production Capability*' together can predict 74.7% of the variance in '*Sales Performance*' variable the other input variable will add little to the variance.

Table 4.16 Regression analysis for Innovation Performance

Dependent Variable			R	R Square	Adjusted R Square	F Probability
Innovation Performance (Z1)			0.593	0.352	0.293	0.009
S.No.	**Independent Variable(s)**	**B**	**β**	**Standard Error**	**t-value**	**Significance**
1	**Investment Capability (I1)**	0.047	0.033	0.374	0.126	0.901
2	**Production Capability (I2)**	0.683	0.568	0.313	2.183	0.040

Table 4.17 Regression analysis for Sales Performance

Dependent Variable			R	R Square	Adjusted R Square	F Probability
Sales Performance (Z2)			0.881	0.776	0.744	0.000
S.No.	**Independent Variable(s)**	**B**	**β**	**Standard Error**	**t-value**	**Significance**
1	**Investment Capability (I1)**	0.433	0.371	0.185	2.340	0.029
2	**Production Capability (I2)**	0.434	0.444	0.153	2.837	0.010
3	**Linkage Capability (I3)**	0.397	0.328	0.128	3.107	0.005

Table 4.18 shows the regression analysis with the dependent variables as '*Product Performance*' and the three input factors as independent variables. The results indicate that, '*Investment Capability'*, and '*Production Capability*' together can predict 46.7 % of the variance in '*Product Performance*' variable the other input variables will add little to the variance.

Table 4.18 Regression analysis for Product Performance

Dependent Variable			R	R Square	Adjusted R Square	F Probability
Product Performance (Z3)			0.715	0.512	0.467	0.000
S.No.	**Independent Variable(s)**	**B**	**β**	**Standard Error**	**t-value**	**Significance**
1	**Investment Capability (I1)**	0.354	0.242	0.331	1.070	0.296
2	**Production Capability (I2)**	0.633	0.516	0.277	2.284	0.032

4.7.4 Result Discussion

The positive relation between firm's investment in technological innovation and firm performance has been supported by various arguments: it enables firm to achieve greater capability to meet the demands of its changing domestic and international market, thus give firm a good performance (Zahra and George, 2002). The correlation analysis of '*Investment Capability'* (I1) factors validates the above facts. Investment Capability shows significant positive correlation with '*Innovation Performance'* (Z1) (r=0.629; p=0.001), '*Sales Performance'* (Z2) (r=0.771, p=0.000) and '*Product Performance'* (Z3) (r=0.460; p=0.021). '*Investment Capability'* (I1) input factor consists of three main sub factors viz. Investment in tangible assets, Investment in intangible assets and In-house R&D. It also enables firm to exploit the intangible technological assets, which can be beneficial to the learning process (Xie, 2004). Literature reveals that the spending that a firm makes in different innovation activities (e.g. in-house R&D, purchasing license and patents etc.) shows its commitment to the accumulation of knowledge that will give rise to new products/process or other kinds of innovation. Investment capabilities are the skills to identify needs, prepare and obtain the necessary technology, then design, construct, equip, and staff the facility, before a new facility is commissioned or existing plant is expanded (Salomon *et al.,* 1994). All these three factors together combined lead to growth of organization and enhancement in innovation related activities of the organization which is evident from the correlation analysis which shows a significant correlation with all the three research output parameters.

Production capabilities start from the last step of the first typology: basic technology skills, like quality control, operation, and maintenance to more advanced ones like adaptation or improvement to research, design, and innovation. This implies in some way technology mastery and in others, minor or major innovation (Lall, 1987). The correlation analysis of '*Production Capability*' (I2) shows that '*Production Capability*' (I2) has significant positive relation with '*Innovation Performance*' (Z1) (r=0.697; p=0.000), '*Sales Performance*' (Z2) (r=0.764; p=0.000) and '*Product Performance*' (Z3) (r=0.573; p=0.002). Zahra and Covin (1994) indicates that a firm's production capabilities in product development do have a positive influence on firm performance.

Linkage Capability according to literature involves following activities: local procurement of goods nad services, information exchange with suppliers, import of technology, cooperative R&D, licensing own technology to others and lending own machinery and equipments for training or production related activities to collaborating organization. Such linkages affect not only productive efficiency of the enterprise but also diffusion of technology thus enabling the organizations to specialize more fully in their products and producing products with better features and quality (Lall, 1992; Kumar and Bala Subrahmanya, 2010). Survey result also shows that '*Linkage Capability*' (I3) has significant positive relation with '*Sales Performance*' (Z2) (r=0.458; p=0.021)). Partnerships with suppliers or larger firms generally lead at significant quality improvements or cost reductions due to process innovations (Classen *et al.*, 2012).

4.8 Chapter Summary

The chapter describes the quantitative analysis performed on the data using various statistical tools. Status of key input and output performance parameters has been determined. Further, all the manufacturing units surveyed have been classified as very good, good, poor etc based on their status in key issues. Significance and correlation of input parameters with output parameters have been found out through step-wise regression analysis and pearson's correlation analysis. Principal Component analysis has been used to reduce various key issues under each input parameter to few important components.

CHAPTER - V

CONCLUSIONS

5.1 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 results of the survey and the inferences drawn from them along with the major learnings. Based on the results and the findings, conclusions have been drawn and recommendations have been made. The limitations along with the scope for future work are covered in the subsequent sections of the chapter.

5.2 Results and Major Findings

The various results have been derived on the basis of quantitative analyses performed on the data. The main findings are presented as follows:

Investment Capability

- Effective utilization of resources by an organization results in benefits by providing the customer order of the product at the right time with a better quality. The manufacturing units have shown relatively good response (PPS=72.00). Nearly half of the units (44%) make use of resource to a moderate extent only.
- Most of the units do not have a state of the art production technology. There are only a very few units (12%) which to a large extent use latest production machinery, tooling and equipment.
- The small units in the region have shown a relatively poor response (PPS=39.20) to the investment in intangible assets. There are 16% units which do not make any investment in intangible assets like patent, licenses etc.
- Most of the units (80%) have never applied for a patent or obtained it.
- Most of the units (68%) provide training, either during orientation period through senior executives or on-the-job training where employees learn through experience. Surprisingly, none of the organizations make use of standard creativity tests to improve innovation level of

employees. Also, there is no encouragement to participate in conferences, workshops, seminars etc.

- The state of affairs in the industry is disappointing (PPS= 25.60) as far as earmarking of funds specifically for research activities is concerned. Most of the units (88%) do not clearly allocate funds for research and development initiatives.

Production Capability

- Most of the units (76%) have been found to be just moderately focusing on human resource management.
- The small scale sector is showing a relatively poor rating (PPS=55.20) with regards to process management. Most of the units (92%) focus on process management issues only moderately or to a small extent.
- The small scale sector shows a relatively good rating (PPS=71.20) in terms of customer focus. About half of the units (48%) have been found to be good to a large extent in this issue.
- Most of the organizations (68%) lack in quality planning at their units. The remaining units focus on these issues only moderately or to a small extent.
- Organization structure also show poor rating (PPS=55.20). Most of the organizations (48%) focus on their organization structure to a moderate extent. Few of the units (40%) focus on this issue to a small extent. Organization structure is the formal structure of task and reporting relationships that control, coordinate, and motivate employees so that they cooperate to achieve organization's goals.
- In most of the units (60%), senior managers actively encourage change and implement a culture of trust, involvement and commitment in moving towards 'Best Practice' to a marginally extent and few of the units (44%) are extremely good in using tactical knowledge for innovation and improvements.
- Process and quality improvement programs have obtained a very poor status (PPS=33.60) of the manufacturing organization. Most of the organizations (56%) have obtained benefits only to a small extent from such program. Few of the units (40%) do not obtain benefits at all.
- Most of the organizations (68%) use quality tools only to a small extent on the shop floor. About one third of the units (28%) do not use these tools at all, which is discouraging.

- The cutting tool units have shown a poor rating (PPS=49.60) with regards to policies and procedures for quality control system. Most of the units (60%) have framed and implemented these policies only to a small extent.

Linkage Capability

- Firm's collaboration with external organizations allows the expansion of their range of expertise and can support the development of new products. Majority of the units have obtained positive results only to a small extent through collaboration.
- Subcontracting benefits with large enterprises (56%) is to a small extent. About one third (36%) of the industrial units do not obtain any benefit from subcontracting with large firms.
- Nearly half of the units are not involved in any type of cooperative research with universities.
- A nearly more than half of the units obtain positive results to a small extent only through collaboration and a nearly less than half of the units either do not collaborate with academic institutes or do not obtain positive results through collaboration.
- In majority of the units the status of technology transfer from academia to industry in the region is not available.
- The small scale sector has obtained an extremely poor rating (PPS=20.00) in utilizing university labs for testing and inspection.

Status of Manufacturing Units

- The performance of organizations in '*Investment Capability*' component is not encouraging with an average score of 48.07 %. More than 92% of the units fall in '*Poor*' category in this component. Only 8% units are at a '*Fair*' level.
- The average score of organizations in '*Production Capability*' component is 52.9%. Only 4% of the units are at 'Good' level. Nearly three fifth of the units are at a 'Poor' level and about one third of the units are at 'Fair' level.
- The performance of organizations in '*Linkage Capability*' component is poor with an average score of 32.96 %. None of the units fall even in 'Fair' category. About 56 % of the units fall in '*Poor*' category in this component. 44 % units are at a '*very poor*' level.

Results of Correlation Analysis

The results of correlation analysis between independent and dependent variables show that:

- ‘*Investment Capability’* (I1) is significantly correlated with ‘*Innovation Performance*’ (Z1), ‘*Sales* Performance’ (Z2) and with ‘*Product Performance*’ (Z3).
- ‘*Production Capability’* (I2) has established a significant positive correlation with ‘*Innovation Performance*’ (Z1), ‘*Sales* Performance’ (Z2) and with ‘*Product Performance*’ (Z3).
- ‘*Linkage Capability*’ (I3) has shown significant association with ‘*Sales Performance*’ (Z2).

Results of Regression Analysis

- 29.3% of the variance in ‘*Innovation Performance*’ can be predicted from ‘*Investment Capability*’ and ‘*Production Capability’*.
- 74.7% of the variance in ‘*Sales Performance’* parameter can be predicted from input variables viz. ‘*Investment Capability’, ‘Production Capability’* and ‘*Linkage Capability’*.
- 46.7% of the variance in ‘*Product Performance*’ can be predicted from ‘*Investment Capability*’ and ‘*Production Capability’*.

Results of Principal Component Analysis

- The eleven issues under ‘Investment Capability’ input factor can be reduced to three components. This is achieved by combining availability of better production technology, investment in intangible assets, use of intellectual property as a strategic tool, use of tactical knowledge and investment in R&D as a proportion of annual turnover into the first component; earmarking of funds for R&D and research and innovation initiatives for process improvements into second component and the third component can be interpreted to be comprising of investment in tangible assets, effective utilization of resources, availability of better production technology.
- Principal component analysis extracted three components among nine items of ‘Production Capability’. The first component can be interpreted from process management, customer focus, planning, organization structure, use of quality tools on shop floor and policies and procedures for quality control. Leadership and process and quality improvement program and combined make the second component whereas human resource management, customer focus and organization structure reflect the third component of this input variable.
- ‘Linkage Capability’ factor can also be compressed to three components by combining industry- industry alliance with positive results, subcontracting benefits with large

enterprises, cooperative research with institutes for R&D projects and industry-academia alliance with positive results and university labs for testing and inspection into the first component. Benefits through collaborations with small units, university labs for testing and inspection and combined supervision of thesis constitute the second component. Contract based research institutes and Expert lectures and training programmes by academicians reflect the third component of this input variable.

5.3 Conclusions

The outcomes of previous phases (survey based empirical study and literature review) have been synthesized and presented in the form of conclusions in this section. The various issues are presented as follows:

- Small units realize the importance of investment in purchasing the tangible assets to maintain the state of the art technology. Most of the units in the region increased their investment in this regard.
- Lack of investment in intangible assets in small scale units has been a major problem. The small units which are not making investment in intangible assets are also unaware about the intellectual property rights as a strategic tool.
- Small firms have not being doing well in the training of employees. Most of the units provide on the job training where employees learn through experience only.
- Small firms have lacked in research and innovation activities for process improvements. Lack of investment for R&D related activities have been a critical factor impairing innovation performance.
- Management leadership fosters change in an organization through continuous improvement and open communication and this potentially explains the improvement in financial performance, customer service and product quality. The manufacturing organizations surveyed have shown only a moderate performance in this issue.
- There has been lack of process management in small scale units. There is lack of efforts aimed at managing and continually reducing process variation leading to continuous quality improvement.

- Lack of quality planning activities has been a major problem in small scale units. Quality planning activities affect human resource management and also process management. There is a need for the units to plan its activities to improve quality.
- Small firms have lacked in having a proper organizational structure. It is the formal structure of task and reporting relationships that control, coordinate, and motivate employees so that they cooperate to achieve organization's goals.
- Small firms have lacked in using quality tools (such as Pareto Charts, Ishikawa Diagrams, Control Charts, Fault Tree Analysis etc.) on the shop floor. Use of these tools on the shop floor can improve the production capability of organizations.
- Lack of clear the policies and procedures for quality control has been a major problem in small scale units. Clearly defined Policies and procedures for quality control system are very important for the effective working of any quality management program.
- Lack of industry-industry collaboration with positive results in small scale units has been a major problem. Industries need to work together towards a common goal by sharing information and resources in order to undertake joint projects.
- Effective collaborations require changing of some established practices and learning across different organizational cultures. Small units have failed to adopt these measures.
- Small scale firms have lacked in subcontracting relationship with LEs .Subcontracting relationship of SMEs with LEs is an important source for transfer of technologies, leading to innovative performance of SMEs. However, the survey results indicate a very poor status of small units in terms of forging subcontracting relations with large enterprises and obtaining benefits through such collaborations. Most of the units have received benefits only to a very small extent by forging such relations.
- Lack of cooperative research in small scale firms has been a major problem. Most of the units are not involved in any type of cooperative research with universities.
- Small scale manufacturing units are not interacting much with universities and external research institutes for technology development. Firms and universities need to apply thinking strategies to their surroundings, to increase collaborations and knowledge sharing while ensuring that sufficient mutual benefits can be derived.

- Manufacturing organizations are not collaborating much with external research institutes and universities. These issues need critical and thorough investigation and there is need to focus on industry-university collaboration.
- Small scale firms have lacked in testing and inspection in university labs. University labs can be an important source for testing and inspection related activities for small units as such units are unable to procure costly equipments themselves.

5.4 Limitations of the Study

The main limitations of the study are as follows:

i) The study has been limited to only small units of the region. The study has not taken into consideration effect of parameters like firm age, turnover etc. on the result outcome.

ii) The item measures identified for various constructs have been considered to be of equal importance in the study, however in actual situation, some item measures may be more important than the others. The study can be extended by attaching appropriate weights to these item measures through qualitative techniques.

iii) The present study has taken into consideration the manufacturing industry only and can be extended to other categories of industry. Also, it can be carried out for large scale manufacturing sector.

iv) Principal component analysis has been used in the present work to reduce the number of components comprising a factor. Correlation analysis between each individual input component and output performance parameters could have been investigated.

The present research is aimed at developing an insight into the technology capability initiatives adopted in the manufacturing industry for realizing sustainable growth. Without doubt the most innovative companies of the future will be dominated by those that do not simply focus energies upon product and technical innovation, but those who manage to build enduring environments of human communities striving towards innovation through the creation of appropriate cultures and climate.

REFERENCES

- Acs, Z.J. and Audretsch, D. (1990) 'Innovation and Small Firms', *MIT Press, Cambridge*.
- Adler, P.S. and Shenbar, A. (1990) 'Adapting your technological base: the organizational challenge', *Sloan Management Review,* Vol. 25, pp. 25–37.
- Adler, P.S. and Clark, K.B. (1991) 'Behind the Learning Curve: A Sketch of the Learning Process', *Management Science,* Vol. 37, pp. 267-281
- Agboolac, A.A., Olamadeb, O.O. and Oyebisia, T.O. (2004) 'An assessment of the level of availability of technological capabilities in the Nigerian telecommunications industry', *International Journal of Information Management,* Vol. 24, pp. 423–432.
- Amidon, D. (2003) 'The Innovation Highway', *Boston: Butterworth-Heinemann.*
- Angel, D. P. (2002) 'Inter-firm collaboration and technology development partnerships within U.S. manufacturing industries', *Regional Studies*, Vol.36, pp.333–344.
- Aw, B.Y. and Batra, G. (1998) 'Technological capabilities and firm efficiency in Taiwan (China)', *World Bank Economic Review,* Vol.12, pp. 59-79.
- Baark, E., Antonio, Lau, K.W., Lo, W. and Sharif, N. (2011) 'Innovation Sources, Capabilities and Competitiveness: Evidence from Hong Kong Firms', *Paper presented at the DIME Final Conference, Maastricht.*
- Babbie, E. (1990) 'Survey Research Methods', *California, USA: Wadsworth Publishing Company*.
- Banbury, C.M. and Mitchell, W. (1995) 'The Effect of Introducing Important Incremental Innovations on Market Share and Business Survival', *Strategic Management Journal,* Vol.16, pp. 161-182.
- Banerjee, P.M. (2012) 'From information technology to bioinformatics: Evolution of technological capabilities in India', *Technological Forecasting & Social Change*, Vol. 79, pp.665-675.
- Becheikh, N., Landry, R. and Amara, N. (2006) 'Lessons from Innovation Empirical Studies in the Manufacturing Sector: A Systematic Review of the Literature from 1993–2003', *Technovation,* Vol. 26, No. (5/6), pp. 644-664.
- Bell, M. and Pavitt, K. (1993) 'Technological accumulation and industrial growth: Contrasts between developed and developing countries', *Industrial and Corporate Change,* Vol. 2, pp.157-209.
- Bessant, J. and Tidd, J. (2007) 'Innovation and Entrepreneurship', *Wiley: Chichester, UK*.
- Best, J.W. and Kahn, J.V. (1986) 'Research in Education', *Prentice Hall of India Ltd*., New Delhi, pp. 145-146.
- Betts, S.C., and Santoro, M.D. (2011) 'Somewhere between markets and hierarchies: Controlling industry university relationships for success', *Academy of Strategic Management Journal,* Vol. 10, No. 1, pp.19-43.
- Bougrain, F. and Haudeville, B. (2002) 'Innovation,collaboration and SMEs internal research capacities', *Research Policy* , Vol.31, pp.735-747.
- Bowen, D.E. and Lawler, E.E. (1992) 'Total quality-oriented human resources management', *Organizational Dynamics, Vol.* 20, No. 4, pp. 29–41.
- Brockhoff, K. (1991) 'Research and development cooperation between firms. A classification by structural variables', *International Journal of Technology Management,* Vol. 6, pp.361-373.
- Bryman, A., and Cramer, D. (2005) 'Quantitative Data Analysis with SPSS 12 and 13', *East Sussex, England: Routledge Press.*
- Burgelman, R., Maidique, M.A. and Wheelwright, S.C. (2001) 'In: Strategic Management of Technology and Innovation', *McGraw-Hill,* New York, pp. 10–14.
- Burrone, E. and Jaiya, G.S. (2005) 'Intellectual Property (IP) Rights and Innovation in Small and Medium-Sized Enterprises', *Geneva: World Intellectual Property Organization.*
- Calantone R.J., Vickery S.K. and Dröge C. (1995) 'Business Performance and Strategic New Product Development Activities: An Empirical Investigation', Vol.12, pp.214-223.
- Camison, C. and Lopez, A.V. (2011) 'Non technical innovation: Organizational memory and learning capabilities as antecedent factors with effects on sustained competitive advantage', *Industrial Marketing Management*, Vol. 40, pp.1294–1304.
- Caniels, M. and Romijn, H. (2001) 'Small-industry clusters, accumulation of technological capabilities, and development: A conceptual framework', *Working Paper 01.05, ECIS.*
- Chakravarty, B. (1986) 'Measuring strategic performance', *Strategic Management Journal,* Vol.7, pp.437-458.

- Chaminade, C. and Vang, J. (2006) 'Innovation Policies for Asian SMEs: An Innovation System Perspective', In H. Yeung (ed.), *Handbook of Research on Asian Studies,* Cheltenham: Edward Elgar.
- Chiesa, V., Coughlan, P. and Voss, C.A. (1998) 'Development of a technical innovation audit', *IEEE Engineering Management Review,* Vol. 26, No. 2, pp. 64–91.
- Christensen, C. M. (1997) 'The innovator's dilemma: When new technologies cause great firms to fail', *Boston: Harvard Business School Press.*
- Christensen, C. M. and Raynor, M. (2003) 'The innovator's solution', *Boston: Harvard Business School Publishing.*
- Churchill, G.A. (1995) 'Marketing Research', *Methodological Foundations*, London, Dryden.
- Christensen, J.F. (1995) 'Asset profiles for technological innovation', *Research Policy,* Vol. 24, pp.727-745.
- Clark, K. and Fujimoto, T. (1991) 'Product Development Performance', *Boston: Harvard Business School Press.*
- Classen, N., Gils, A.V., Bammens, Y. and Carree, M. (2012) 'Accessing Resources from Innovation Partners: The search breadth of family SMEs', *Journal of Small Business Management,* Vol. 50, No. 2, pp. 191-215.
- Cohen W., Florida R., Randazzese L. and Walsh J. (1998) 'Industry and the academy: uneasy partners in the cause of technological advance, in NOLL R. (Ed.) Challenges to Research Universities', pp. 171-200.
- Cohen, W. and Levinthal, D. (1990) 'Absorptive capacity: a new perspective on learning and innovation', *Administrative Science Quarterly,* Vol. 35, No. 1, pp.128-152.
- Coombs, J. E. and Bierly, P. E. (2006) 'Measuring technological capability and performance', *R&D management,* Vol. 36, No. 4, pp.421-438.
- Creswell, J.W. (2003) 'Research Design – Qualitative, Quantitative and Mixed Methods Approaches', *London, England: Sage Publications, Inc*.
- Dalton, D., Daily, C., Ellstrand, A. and Johanson, J. (1998) 'Meta-analytic reviews of board composition, leadership structure, and financial performance', *Strategic Management Journal,* Vol. 19, pp. 269-290.
- DeCarolis, D. and Deeds, D. (1999) 'The impact of stocks and flows of organizational knowledge on firm performance: an empirical investigation of the bio-technology industry', *Strategic Management Journal,* Vol. 20, pp. 953-968.
- Deeds, D., DeCarolis, D. and Coombs, J. (1997) 'The impact of timing and firm capabilities on the amount of capital raised in an initial public offering: evidence from the biotechnology industry', *Journal of Business Venturing,* Vol. 12, pp. 31-46.
- D'Este, P., and Patel, P. (2007) 'University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry?', *Research Policy,* Vol. 36, pp.1295–1313.
- Devins, D. and Kimbara, T. (2007) 'Competitive advantage of SMEs in manufacturing industries: A comparison between the UK and Japan', *Local Economy,* Vol.12, No.2, pp. 133-145.
- Dosi, G. (1988) 'The nature of the innovative process', In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soethe (eds.), *Technical change and economic theory, (London: Pinter).*
- Drucker, P. F. (2006) 'Innovation and entrepreneurship (18th ed.)', *New York: Harper Collins*.
- Edwards, T., and Delbridge, R. (2001), 'Linking innovative potential to SME performance: an assessment of enterprises in industrial South Wales, paper for 41st European regional science association meeting, Zagreb, Croatia, August 2001. Available on www.ersa.org/ersaconfs/ersa01/paper/full/135.pdf
- Edwards, T., Delbridge, R. and Munday, M. (2005) 'Understanding innovation in small and medium-sized enterprises: a process manifest', *Technovation,* Vol. 25, pp.1119-1120.
- Ernst, D, Ganiatsos, T. and Mytelka, L. (1998) 'Technological Capabilities and Export Success in Asia', *London, Routledge.*
- Escalfoni, R., Braganholo, V. and Borges, M. (2011) 'A method for capturing innovation features using group storytelling', *Expert Systems with Applications,* Vol. 38, pp. 1148-1159.
- Feng, C., Qi, D., and Sun, B. (2011) 'Policy Suggestions on Innovation and Development of China's Industry-University-Research Strategic Alliance', *International Journal of Business and Management,* Vol. 6, No. 1, pp. 269-273.
- Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., Flynn, J. B. (1990) 'Empirical research methods in operations management', *Journal of Operations Management* 9, pp. 250-284.
- Forsman, H. (2011) 'Innovation capacity and innovation development in small enterprises. A comparison between the manufacturing and service sectors', *Research Policy,* Vol. 40, pp.739-750.

- Franko, L. (1989) ‘Global corporate competition: who's winning, who’s losing, and the R&D factor as one reason why’, *Strategic Management Journal,* Vol. 10, pp. 449-474.
- Freeman, C. and Perez, C. (1988) ‘Structural Crises of Adjustment; Business Cycles and investment behaviour, in: G. Dosi et al. (eds.)’, *Technical Change and Economic Theory (London, Pinter).*
- Freel, M.S. and Harrison, R.T. (2011), Innovation and Cooperation in the Small Firm Sector: Evidence from ‘Northern Britain’, *Regional Studies*, Vol. 40, No.4, pp. 289-305.
- Gammeltoft, P. (2010) ‘Development of firm-level technological capabilities’, *Journal of the Asia Pacific Economy,* Vol. 9, No. 1, pp. 49-69.
- Guan, J. and Ma, N. (2003) ‘Innovative capability and export performance of Chinese firms’, *Technovation,* Vol. 23, No. 9, pp. 737-747.
- Guan, J.C., Yam, R.C.M., Mok, K.C., and Ma, N. (2006) ‘A study of the relationship between competitiveness and technological innovation capability based on DEA models’, *European Journal of Operational Research,* Vol. 170, pp. 971-986.
- Hadjimanolis A. (2000) ‘An investigation of innovation antecedents in small firms in the context of a small developing country’, *R&D Management,* Vol. 30, No.3, pp. 235-245.
- Harrison, N. J. and Watson, T. (1998) ‘The Focus for Innovation in Small and Medium Service Enterprises’, *Conference Proceedings of the 7th Annual Meeting of the Western Decision Sciences Institute,* 7–11 April, Reno, NV, USA.
- Hitt, M. and Ireland, R. (1985) ‘Corporate distinctive competence, strategy, industry and performance’, *Strategic Management Journal,* Vol. 6, pp. 273-293.
- Hobday (1995) ‘Innovation in East Asia: The Challenge to Japan’, *Cheltenham, Edward Elgar.*
- Hoffman, K., Parejo, M., Bessant, J. and Perren, L. (1998) ‘Small Firms, R&D, Technology and Innovation in the UK: A Literature Review’, *Technovation,* Vol. 18, No. 1, pp. 39-55.
- Hyland, P. and Beckett, R. (2005) ‘Engendering an innovative culture and maintaining operational balance’, *Journal of Small Business and Enterprise Development,* Vol. 12, No. 3, pp. 336-352.
- Jagersma, T. (2008) ‘Innovation in Small Scale Industries in Kerala’, *Bachelor Assignment, Universiteit twente, Technology and Development Group* , Enschede, The Netherlands.
- Jimenez, D.J. and Raquel, S.V. (2011) ‘Innovation, organizational learning, and performance’, *Journal of Business Research,* Vol. 64, pp. 408-417.
- Jung, D., Chow, C. and Wu, A. (2003) ‘The role of transformational leadership in enhancing organizational innovation: hypotheses and some preliminary findings’, *Leadership Quarterly,* Vol.14, pp. 525-544.
- Kaynak, H. (2003) ‘The relationship between total quality management practices and their effects on firm performance’, *Journal of Operations Management*, Vol. 21, pp. 405–435.
- Keith, S. (1997) ‘Policy Options for the Norwegian SME Sector, Draft Report to NFR’, *Oslo: STEP Group.*
- Kim, Linsu (1997) ‘Imitation to Innovation: the Dynamics of Korea’s Technological Learning’, Boston, *Mass.: Harvard Business School Press.*
- Kong, F., Zhang, Z. and Liu, Y. (2008) ‘Study on the evaluation of technological innovation capability under uncertainty’, *IEEE.*
- Kumar, R.S. and Bala Subrahmanya, M.H., (2010) ‘Influence of subcontracting on innovation and economic performance of SMEs in Indian automobile industry’, *Technovation,* Vol. 30, pp. 558-569.
- Lall, S. (1987) ‘Learning to industrilize: the acquisition of Technological Capability by India’, *London: Macmillan.*
- Lall, S. (1990) ‘Building Industrial Competitiveness in Emerging Countries’, *Paris: OECD.*
- Lall, S. (1992) ‘Technological capabilities and industrialisation’, *World Development,* Vol. 20, pp. 165-186.
- Lall, S., Barba-Navaretti, G., Teitel, S. and Wignaraja, G. (1994) ‘Technology and Enterprise
- Development: Ghana Under Structural Adjustment’, *London, Macmillan.*
- Lall, S. (1995) ‘Industrial adaptation and technological capabilities in developing countries’, in Tony Killick (ed.), The Flexible Economy: Causes and Consequences of the Adaptability of National Economies, *London: Routledge.*
- Lau, K.W., Lo, W.,Yam,R.C.M. and Tang, E.P.Y. (2010) ‘Technological innovation capabilities and firm performance’, *World Academy of Science, Engineering and Technology* Vol. 66, pp. 1023-1031.
- Lee, J. (1995) ‘Small firms’ innovation in two technological settings’, *Research Policy,Vol.* 24, pp. 391- 401.
- Lendel, V. and Varmus, M. (2011) ‘Creation and Implementation of the Innovation Strategy in the Enterprise’, *Economics and Management,* Vol. 16, pp. 819-825.

- Liao, Y., Fan, Y. and Xi, Y. (2011) ‘A technological innovation management based on the audit’, *International Business Research,* Vol. 4, No. 2, pp. 170-174.
- Litwin, M.S. (1995) ‘How to Measure Survey Reliability and Validity’, *London, England: Sage Publications Inc.* Longenecker, C. O., Simonetti, J. L., and Sharkey, T. W. (1999) ‘Why organizations fail: the view from the front-line’, *Management Decision*, Vol. 37, No. 6, pp.503-513.
- Mansfield, E. (2000) ‘Intellectual property protection, direct investment and technology transfer: Germany, Japan and the USA’, *International Journal of Technology Management*, Vol.19, No. 1, pp. 3-21.
- Metcalfe, S. (forthcoming) Science, technology and innovation policies in developing countries’, in: G. Wignaraja (ed.) Competitiveness Strategy and Industrial Performance in Developing Countries: A Manual for Policy Analysis, *London, Routledge.*
- Meyanathan, S.D. and Munter, R. (1995) ‘Industrial structures and the development of small and medium enterprise linkages: an overview’, In: Meyanathan, S.D. (Eds.), Industrial Structures and the Development of Small and Medium Enterprise Linkages: Examples from East Asia. EDI Seminar Series, The World Bank, Washington, DC.
- Milson, M.R., Raj, S.P. and Wilemon, D. (1996) ‘Strategic partnering for developing new products’, *Research and Technology Management*, May-June, pp. 41-49.
- Molina,M.A. and Pietrobelli, C. (2012) ‘Drivers of technological capabilities in developing countries: An econometric analysis of Argentina, Brazil and Chile’, *Structural Change and Economic Dynamics*, Article in press.
- Moreau, E.B. and Colakoglu, M. (2011) ‘Impact of SME policies on innovation capabilities: The Turkish case, Science and Technology Policies Research Center’, *TEKPOL Working Paper Series.*
- Mytelka, L. and Farinelli, F. (2000) ‘Local clusters, innovation systems and sustained competitiveness, Mimeo’, *Unuintech, Maastricht.*
- Nair, A. (2006) ‘Meta-analysis of the relationship between quality management practices and firm performance implications for quality management theory development’, *Journal of Operations Management*, Vol. 24, pp. 948–975.
- Nanda, T. and Singh, T.P. (2009) ‘Determinants of creativity and innovation in the workplace: a comprehensive review’, *International Journal of Technology, Policy and Management,* Vol. 9, No. 1, pp. 84-106.
- Nanda, T. and Singh, T.P. (2008) ‘A comprehensive Strategy for Technology Generation through effective Industry-Institute Bonding’, *The Indian Journal of Technical Education,*Vol. 31, No. 2, pp.1-6.
- Narayanan, K., Bhat, S. (2009) ‘Technology sourcing and its determinants: a study of basic chemical industry in India’, *Technovation,* Vol. 29, No. 8, pp. 562-573.
- Nelson, R.R. and Winter, S.J. (1982) ‘An Evolutionary Theory of Economic Change’, *Cambridge, MA, Belknap Press.*
- Oakey, R., Rothwell, R. and Cooper, S. (1988) ‘Management of innovation in high technology small firms’, *Quorum Books.*
- OCDE-Eurostat. (1997) ‘Proposed Guidelines for Collecting and Interpreting’, *Dans Oslo Manuel, Paris: OCDE.*
- OECD (1997) ‘National Innovation Systems’, OECD, Paris.
- O’Leary, Z. (2004) ‘The Essential Guide to Doing Research’, *London, England: SAGE Publications.*
- Ortega, M.J.R. (2010) ‘Competitive strategies and firm performance: Technological capabilities moderating roles’, *Journal of Business Research,* Vol. 63, pp.1273-1281.
- Pack, H. and Westphal, L. E. (1986) ‘Industrial strategy and technological change: theory versus reality’, *Journal of Development Economics,* Vol. 22, pp. 87-128.
- Panda, H. and Ramanathan, K. (1996) ‘Technological capability assessment of a firm in the electricity sector’, *Technovation,* Vol. 16, No.10, pp. 561-588.
- Patel P. and Pavitt K. (1998) ‘National systems of innovation under strain: the internationalization of corporate R&D’, *Electronic Working Paper, SPRU.*
- Prakash, Y. and Gupta, M. (2008) ‘Exploring the relationship between organisation structure and perceived innovation in the manufacturing sector of India’, *Singapore Management Review,* Vol. 30, No.1, pp. 55-76.
- Pun, K.F., Chin, K.S., Yam, R.C.M., and Gaun, J.C. (2006) ‘Technology transfer and innovation performance: Evidence from Chinese firms’, *Technological Forecasting & Social Change,* Vol. 73, pp. 666-678
- Radhakrishna, R. B. (2007) ‘Tips for developing and testing questionnaires/instruments’, *Journal of Extension, Vol.* 45, No. 1, article 1TOT2.

- Rasmussen, E., Moen, O. and Gulbrandsen, M. (2006) 'Initiatives to promote commercialization of university knowledge', *Technovation*, Vol. 26, pp.518-33.
- Raymond, L. and St-Pierre, J. (2010) 'R&D as a determinant of innovation in manufacturing SMEs: An attempt at empirical clarification', *Technovation,* Vol. 30, pp. 48-56.
- Romijn, H. (1997) 'Acquisition of Technological Capabilities in Development: A quantitative Case Study of Pakistan's Capital Goods Sector', *World Development*, Vol. 25, No. 3, pp. 359-377.
- Rothwell R. (1991) 'External neworking and innovation in small and medium-sized manufacturing firms in Europe', *Technovation,* Vol.11, No.2, pp. 93-112.
- Rothwell, R. (1993) 'The changing nature of the innovation process: implications for SMEs', paper presented to the Conference on New Technology Based Firms in the 1990s, *Manchester Business School,* 25th- 26th June.
- Rothwell R. and Dodgson M. (1994) 'Innovation and Size of Firm', In. M. Dodgson and R. Rothwell (eds.), *The Handbook of Industrial Innovation,* Edward Elgar, Aldershot: pp. 310-324.
- Saaty, T.L. (1980) 'The Analytical Hierarchy Process', *McGraw Hill*, New York.
- Saaty, T.L. (1982) 'Decision making from Leaders', *Lifetime Learning Publications*, Belmont, CA.
- Saaty, T.L. (1986) 'Axiomatic Foundation of the Analytical Hierarchy Process', *Management Science*, Vol. 32, No. 7, pp. 841-855.
- Saaty, T. L. (1990) 'How to make a Decision: The Analytical Hierarchy Process', *European Journal of Operations Research,* Vol. 48, No. 1, pp. 9-26.
- Salomon, J.J., Sagasti, F.R. and Jeantet, C.S. (eds.) (1994) 'The uncertain quest: Science, Technology and Development', Number UNUP-835, *United Nations University Press.*
- Sok, P. and O'Cass, A. (2011) 'Achieving superior innovation-based performance outcomes in SMEs through innovation resource-capability complementarity', *Industrial Marketing Management*, Vol. 40, pp.1285-1293.
- Suarez, F.F., Cusumano, M.A. and Fine, C.H. (1996) 'An empirical study of manufacturing flexibility in printed circuit board assembly', *Journal of Operations Research*, Vol. 44, No. 1, pp. 223-240.
- Schumpeter, J. (1942) 'Capitalism, Socialism and Democracy', *New York: Harper*
- Shan, J. and Jolly, D.R. (2010), 'Accumulation of Technological Innovation Capability and Competitive Performance in Chinese firms: A quantitative study', IAMOT, Cairo, Egypt.
- Strišš, J., Vodák, J., Kubina, M., Jankal, R. and Soviar, J. (2009) 'Marketingové riadenie. Žilina: EDIS-vydavateľstvo ŽU', ISBN 80-8070-680-7.
- Sushil (1997a) 'Flexibility in technology management: global imperatives', *Proceedings of the International Conference on Management of Technology* (ICMOT'97), New Delhi: IIT, Dec 21-24, pp. 219-25.
- Sushil (1997b) 'Flexible systems management: an evolving paradigm', *System Research and Behavioral Science*, Vol. 14, No. 4, pp. 259-75.
- Sushil, (2000) 'Situation-Actor-Process options: Mapping and enhancing flexibility', S*ystems Research and Behavioral Science*, Vol. 17, Issue 3, pp. 301-309.
- Tang, E.P.Y., Yam, R.C.M. and Lau, A.K.W. (2010) 'The impact of technological innovation capabilities on innovation performance: An empirical study in Hong Kong', *Journal of Science and Technology Policy in China,* Vol. 1, No. 2, pp. 163-186.
- Tari, J.J., Molina, J.F. and Castejon, J.L. (2007) 'The relationship between quality management practices and their effects on quality outcomes', *European Journal of Operational Research*, Vol. 183, pp. 483–501
- Tellis, G. J., Prabhu, J. C. and Chandy, R. K. (2009) 'Radical innovation across nations: The preeminence of corporate culture', *Journal of Marketing*, Vol. 73, No. 1, pp. 3-23.
- Tidd, J., Bessant, J. and Pavitt, K. (2001) 'Managing for innovation, integrating technological, market and organizational change', *Sussex: John Wiley and Sons.*
- Tidd, J., Bessant, J. and Pavitt, K. (2002) 'Managing Innovation: Integrating Technological, Market and Organizational Change', 2nd ed., *Chichester: Wiley.*
- Tierney, P., Farmer, S.M. and Graen, G.B. (1999) 'An examination of leadership and employee creativity: the relevance of traits and relationships', *Personnel Psychology*, Vol. 52, pp.591- 620.
- Tsekouras, K., Tsegnidi, K. and Skuras, D.(2008) 'Product innovation and decision to invest in fixed capital assets: Evidence from an SME survey in six European union member states', *Research Policy*, Vol. 37, pp. 1778-1789.
- UNCTAD, (2001) 'World Investment Report 2001: promoting linkages, New York and Geneva, Part II—Promoting linkages between foreign affiliates and domestic firms'.

- Warfield, J.L. (1979) 'System Planning for Environmental Education', *IEEE Transactions,* Vol. SMC-9, No.12, pp. 816-823.
- Warfield, J.L. (1982) 'Consensus Methodologies', *Centre for Interactive Management*, Charlottesiville.
- Warfield, J.L. (1990) 'A Science of Generic Design: Managing Complexity through System Design', *Intersystems,* Vol. 1, Salinas, CA.
- Wignaraja, G. (2002) 'Firm Size, Technological Capabilities and Market-oriented Policies in Mauritius', *Oxford Development Studies,* Vol. 30, No. 1, pp. 88-102.
- Wignaraja, G. (2012) 'Innovation, learning, and exporting in China: Does R&D or a technology index matter?', *Journal of Asian Economics*, Vol. 23, pp. 224–233.
- Westphal, L. E., Kim, L. and Dahlman, C. J. (1985) 'Reflections on the Republic of Korea's acquisition', International Technology Transfer: Concepts, Measures and Comparisons, pp.167–221, *New York: Praeger.*
- Westphal, L.E. (2001) 'Technology strategies for economic development in a fast changing global economy', Mimeo, *Swarthmore College, Swarthmore, PA.*
- Wheelen, T.L. and Hunger, J.D. (1999) 'Strategic Management and Business Policy', *Addison-Wesley: Reading,* MA.
- Wolfe, B. (1994) 'Organizational Innovation: Review, Critique, and Suggested Research Directions', *Journal of Management Studies,* Vol.35, pp. 405-431.
- Wolpert, J. (2002) 'Breaking Out of the Innovation Box', *Harvard Business Review,* pp. 77-83.
- Wong, P.K. (1999a) 'National Innovation Systems for Rapid Technological Catch-up: An analytical framework and a comparative analysis of Korea, Taiwan and Singapore', Druid Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, Rebuild, Denmark.
- Xie, W. (2004) 'Technological learning in China's colour TV industry', *Technovation,* Vol. 24, No. 6, pp.499-512.
- Yam, R.C.M., Guan, J. C., Pun, K. F. and Tang, P.Y.E. (2004) 'An audit of technological innovation capabilities in Chinese firms: some empirical findings in Beijing, China', *Research Policy,* Vol. 33, pp.1123-1140.
- Yam, R.C.M., Tang, E.P.Y. and Lau, K.W. (2010) 'The impact of technological innovation capabilities on innovation performance An empirical study in Hong Kong', *Journal of Science and Technology Policy in China,* Vol. 1, No. 2, pp. 163-186.
- Yam, R.C.M., William, L., Tang, E.P.Y. and Lau, K.W. (2010) 'Technological innovation capabilities and firm performance' *World Academy of Science, Engineering and Technology*, Vol. 66, pp. 1023- 1031.
- Yang, J. (2007) 'The contingency value of knowledge in new product creativity', International *Journal of Technology Management,* Vol. 40, No.1/2/3, pp. 101-113.
- Yin, X., and Zuscovitch, E. (1998) 'Is firm size conducive to R&D choice? A strategic analysis of product and process innovations', *Journal of Economic Behavior and Organization,* Vol. 35, pp. 243-262.
- Yoon, B., Park, J., Park, G. and Lee, S. (2010) 'Open innovation in SMEs-An intermediated network model', *Research Policy*, Vol. 39, pp. 290-300.
- Zahra, S. (1996) 'Technology strategy and new venture performance: a study of corporate-sponsored and independent biotechnology venture', *Journal of Business Venturing,* Vol. 11, pp. 289-321.
- Zahra, S. and George, G. (2002) 'Absorptive capacity: a review, reconceptualisation and extension', *Academy of Management Review,* Vol. 27, No. 2, pp. 185-203.
- Zheng, K., Zhou and Wu, F. (2009) 'Technological capability, strategic flexibility, and product innovation', *Strategic Management Journal* (*John Wiley & Sons, Ltd.*), Vol. 31, pp. 547-561**.**
- Zhou, G., Zhu, w. and Zhang, H. (2007) 'Innovation Capabilities Evaluation Approach for Chinese Automobile Enterprises', *IEEE.*

APPENDIX – I

Questions under Investment Capability Issues

Issues under Regulatory Corroboration	Questions under each issue
• Investment In Tangible Assets	E1
• Effective Utilization of Resources	E2,E3
• Availability of Better Production Technology	E4,E5
• Investment in Intangible Assets	E6,E8
• Use of Intellectual Property as Strategic Tool	E7,E12
• Employee Training	E9
• Use of Tactical Knowledge	E10,E11
• Earmarked Funds for R&D	E14
• Research and Innovation Initiatives for Process Improvements	E13,E16,E17,E18
• Use of R&D Activities	E19
• Investment in R&D	E15

Questions under Production Capability Issues

Issues under Entrepreneur Role	Questions under each issue
• Leadership	F1
• Human Resource Management	F2
• Process Management	F3
• Customer Focus	F4
• Planning	F5
• Organization Structure	F6
• Process and Quality Improvement Program	F9
• Use of Quality Tool on Shop Floor	F10
• Policies & Procedures for Quality Control System	F6,F8

Questions under Linkage Capability Issues

Issues under Linkage Capability	Questions under each issue
• Industry- Industry alliance in recent past	A3
• Benefits obtained through collaborations with small units	A4, A5, A6, A7, A8
• Subcontracting benefits with large enterprises	A9
• Cooperative research with institutes for joint R&D projects	A10a
• Contract based research with institutes	A10b
• Industry-academia alliance in recent past	A11
• Technology transfer from academia to industry with positive results	A12
• University labs for testing and inspection	A13a
• Expert lectures and training programmes by academicians	A13b
• Combined supervision of thesis	A13d

APPENDIX – II

Principal Components under Investment Capability

Principal Components	*Issues*
Component 1	• Investment in intangible assets • Use of intellectual property as strategic tool • Investment in R&D
Component 2	• Earmarked funds for R&D • Research and innovation initiatives for process improvements
Component 3	• Investment in tangible assets • Effective utilization of resources • Availability of better production technology

Principal Components under Production Capability

Principal Components	*Issues*
Component 1	• Process Management • Planning • Organization structure • Use of quality tools on shop floor • Policies & procedures for quality control system
Component 2	• Leadership • Process and quality improvement program
Component 3	• Human resource management • Customer Focus • Organization structure

Principal Components under Linkage Capability

Principal Components	*Issues*
Component 1	• Industry-industry alliance with positive results • Subcontracting benefits with large enterprises • Cooperative research with institutes for joint R&D projects • Industry-academia alliance with positive results
Component 2	• Benefits through collaborations with small units • University labs for testing and inspection • Combined supervision of thesis
Component 3	• Contract based research with institutes • Expert lectures and training programmes by academicians

APPENDIX – III

t critical value Distribution table

t Distribution						
	α					
Degrees of freedom	.005 (one tail) .01 (two tails)	.01 (one tail) .02 (two tails)	.025 (one tail) .05 (two tails)	.05 (one tail) .10 (two tails)	.10 (one tail) .20 (two tails)	.25 (one tail) .50 (two tails)
1	63.657	31.821	12.706	6.314	3.078	1.000
2	9.925	6.965	4.303	2.920	1.886	.816
3	5.841	4.541	3.182	2.353	1.638	765
4	4.604	3.747	2.776	2.132	1.533	741
5	4.032	3.365	2.571	2.015	1.476	727
6	3.707	3.143	2.447	1.943	1.440	.718
7	3.500	2.998	2.365	1.895	1.415	.711
8	3.355	2.896	2.306	1.860	1.397	.706
9	3.250	2.821	2.262	1.833	1.383	.703
10	3.169	2.764	2.228	1.812	1.372	.700
11	3.106	2.718	2.201	1.796	1.363	.697
12	3.054	2.681	2.179	1.782	1.356	.696
13	3.012	2.650	2.160	1.771	1.350	.694
14	2.977	2.625	2.145	1.761	1.345	.692
15	2.947	2.602	2.132	1.753	1.341	.691
16	2.921	2.584	2.120	1.746	1.337	.690
17	2.898	2.567	2.110	1.740	1.333	.689
18	2.878	2.552	2.101	1.734	1.330	.688
19	2.861	2.540	2.093	1.729	1.328	.688
20	2.845	2.528	2.086	1.725	1.325	.687
21	2.831	2.518	2.080	1.721	1.323	.686
22	2.819	2.508	2.074	1.717	1.321	.686
23	2.807	2.500	2.069	1.714	1.320	.685
24	2.797	2.492	2.064	1.711	1.318	.685
25	2.787	2.485	2.060	1.708	1.316	.684
26	2.779	2.479	2.056	1.706	1.315	.684
27	2.771	2.473	2.052	1.703	1.314	.684
28	2.763	2.467	2.048	1.701	1.313	.683
29	2.756	2.462	2.045	1.699	1.311	.683
Large (z)	2.575	2.327	1.960	1.645	1.282	.675

APPENDIX-IV

Details of Respondents to the Questionnaires

S. No.	Name of Organization	Address	Designation of Respondent	Year of Inception	Main Products
1.	Aro Tech Industries	D-9, Focal Point, Patiala	Proprietor PN Aggarwal 3291462 (O)	2003	*Master Gears, Gear Shaper Cutters, Straight and Spiral Bevel Cutter Blades*
2.	Bhaskar Cutting Tools	D-76, Focal Point, Patiala	Proprieter Bhushan Aggarwal	2009	*Milling Cutters, Piper Cutters*
3.	Canon Tools Company	D-149, Focal Point, Patiala	Proprietor V.S. Arora	1996	*Gear Hobs, Gear Shaper Cutters, Milling Cutters, Dies and Moulds*
4.	Eskay Tool Industries	D-228, Focal Point, Patiala	Proprieter Avtar Singh	2001	*Hobs and Gear Cutters*
5.	Ferro Tech. Tools	C-134, Focal Point, Patiala	Proprietor R.K. Singla 3293454 (O)	2005	*Reamers, End Mill Cutters, Dovetail Cutters, Slitting Saw, Side and Face Cutters*
6.	Ganesh Corporation	D-91, Focal Point, Patiala	Proprieter Ashwani Kumar	1997	*Cutting Tools*
7.	Global Enterprise	C-6, Focal Point, Patiala	Proprietor Sunil K. Sood 2232856 (O)	1995	*Gear Hobs, Gear Shaper Cutters, Milling Cutters, Dies and Moulds*
8.	Jeewandeep Tools	D-110, Focal Point, Patiala	Proprietor Navdeep Gupta 2233915 (O)	1997	*Shank Type Tools,Reamers, End Mill Cutters*
9.	Jyoti Tools	A-18, Industrial Area, Sirhind Road, Patiala	Proprieter Harsh Kumar Mittal	1985	*Form Tools, Gear Hob, Reamer, Centre Drill, Slotting Cutter,T-slot*
10.	Kapson India	D-99, Focal Point, Patiala	Partner Sanjay Kapoor 2216950(O)	1999	*Master Gears Worm, Gear Hobs, Involute Gear Hobs, Gear Shaper Cutters, Gear Shaving Cutters, Involute Gear Cutters*
11.	K.Vee Tools	Sirhind Road, Patiala	Proprieter K.L. Verma		*H.S.S Milling Cutters*
12.	Lalson Tool Corporation	D-277, Focal Point, Patiala	Owner Amit Singla	2002	*H.S.S Cutting Tools*
13.	Module Tools	D-268, Focal Point, Patiala	Proprietor Mitilesh Aggarwal 9988319017(M)	2006	*Hobs, Gear Shaving Cutters, Master Gears, Gear Shaper Cutters*
14.	Perfect Engg. Tools	D-16, Focal Point, Patiala	Proprietor Dilbagh Singh, 5001314 (O)	1994	*Reamers, End Mill Cutters, Dovetail Cutters*
15.	Precision Machines	D-136, Focal Point, Patiala	Proprietor Tejinder Jeet 5003287 (O),	2007	*Shank Type Tools, , Involute Gear Cutters, End Mill Cutters*
16.	P.S. Tools	D-207, Focal Point, Patiala	Proprieter, Neeraj Singla, 9216292234	2012	*Cutting Tools*

S. No.	Name of Organization	Address	Designation of Respondent	Year of Inception	Main Products
17.	R.J. Tools	D -8, Focal Point, Patiala	Partner Mukesh Gupta 2232423 (O)	2003	*Reamers, End Mill Cutters, Dovetail Cutters*
18.	Shakti Tool Industries	D-291, Focal Point, Patiala	Partner Surinder Kumar	2005	*Reamers, End Mill Cutters, Dovetail Cutters*
19.	Shaktiman Tech Tools	D-205, Focal Point, Patiala	Proprieter Gurvinder Singh		*Broaches*
20.	Star Auto Industries	D-57, Focal Point, Patiala	Partner Pritpal Dhiman 5000883 (O)	2004	*End Mill Cutters, Slot Drills, Counter Bore, Convex cutter, Face cutter, Angle cutter*
21.	Super Hobs and Broaches Pvt. Ltd.	B - 22, Focal Point, Patiala	Director Narain Nath, 2232772 (O)	1999	*End Mill Cutters, Side and Face Cutters, Slotting Saw*
22.	Surya Tools Industries	D-97, Focal Point, Patiala	Proprietor Naresh Goyal 3294307 (O)	1998	*Side and Face Cutters, Slotting Saw, End Mill Cutters*
23.	United Broach Company	D-220, Focal Point, Patiala	Proprietor Joginder Singh	2006	*Involute Gear Cutters ,Shank Type Tools, End Mill Cutters,*
24.	Versa Agro Industries	D-33, Focal Point, Patiala	Partner Rahul Tayal	1999	*Cutting Tools*
25.	V.V. Industries	D-86, Focal Point, Patiala	Proprieter Neeraj	2012	*Cutting Tool*