CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The aspect of this chapter is to give a brief outline of the questionnaire that has been prepared as a tool for the analysis of the Advanced Manufacturing Technologies in the Indian Manufacturing industries. A description of the research methodology is presented accompanied by an analysis of the general characteristics of the methods. A structured survey questionnaire has been designed to cover major issues of manufacturing industries and developed hypotheses. This chapter is divided into various sections. The sections cover a discussion on the choice of survey as a data collection method, sampling and data collection procedures, questionnaire design, case study development, as well as data analysis.

3.2 METHODOLOGY

A methodology may be defined how one shall go about studying any phenomenon. Any method to solve a research problem should stem from the problem and the goals of the researcher (Arbnor and Bjerke, 1997). The proper research methods, among others are: the research question of attention, the current state of knowledge about a particular phenomenon and the possibility of using a given process to perform the study (Birnberg et.al, 1990).

Research methodology is about specific research techniques (Silverman, 2000), such as observation, interview, survey, experimental analysis etc. These research techniques can be grouped into qualitative or quantitative approaches. The nature of the problem is an important aspect in determining whether a qualitative or quantitative approach is suitable. The different types of research method represent different types of conclusion for the studies (Furlong et al., 2000). There is no true or false in each practice, slightly more or less effective,
depending on their relation with the theories and methodologies being used and the hypotheses being analyzed, and the research topic that is selected (Silverman, 2000). The research methodologies can be classified as follows:

3.2.1 Quantitative Method

Quantitative research methods initiate in the natural sciences and were originally developed to study natural phenomena (Chen and Hirschheim, 2004). The primary intent of quantitative research is to study facts, test hypotheses, and identify relationships using mathematical and statistical approaches.

The results obtained from the selected sample of population are usually comprehensive to the larger population. The time engaged by the researcher in quantitative methods is generally less (Chen and Hirschheim, 2004). Chisnall (1991) suppose that quantitative research findings tend to be relatively “hard data” in contrast to the “soft data” obtained from qualitative.

3.2.2 Qualitative method

The term ‘Qualitative’ indicate such a broad scope of research methods that a single definition is more or less impracticable; nevertheless, one may define qualitative study as “investigation of knowledge that are outside the framework prescribed by the scientific technique, as well as suppositions of inferential statistics” (Byrne, 2006). Qualitative research techniques engross efficient collection, association, and understanding of different material derived from talk or observation (Malterud, 2001). Simply put, the investigation being carried out is on the why and how of verdict creation, as compared to what, where, and when of quantitative research. Hussey et al., (1997) mentioned that qualitative research involves “examining and reflecting on perceptions” in the hope of achieving a better understanding of the given situation.
While quantitative methods tend to target a large sample population to smooth the progress of the generalization of findings, qualitative methods tend to select smaller samples with a view for identifying patterns or explanations. Inconspicuous measures are measures that do not require the researcher to intrude in the research context. A questionnaire is a distraction in the natural stream of manners. Respondents can acquire weary of filling out survey forms or put out by the questions being asked and this can be one of the main reasons for carrying out qualitative research over quantitative research (Malterud, 2001).

Identifying a brief topic area and having a well-planned research procedure will smooth the progress of completion of a qualitative research study; nevertheless, the research procedure may become known as the researcher gains more information from reviewing the literature, consulting experts, or commencement data compilation. Qualitative research imagines that the researcher is an elementary part of the research process.

### 3.2.3 Laboratory Experiments

The purpose of laboratory experiments is to “test the impact that a treatment or incursion has on a conclusion, while controlling all other features that could have an influence on that conclusion” (Creswell, 2003). This methodology is not suitable for this research as there will be no involvement or influence on the part of the researcher while studying the phenomenon.

### 3.2.4 Survey Questionnaires

According to a study executed by Orlikowski and Baroudi (1991) quantitative surveys are one of the most research methods. Quantitative surveys purpose to reveal data on respondent’s attitudes, opinions, and experiences using predetermined questionnaire material. In addition, survey method is well-known for their quick respondent turnover when collecting data.
Surveys can be conducted in any (or any combination) of these three types; personal or face-to-face interviews, telephone interviews; and mail (Cooper & Schindler, 2001; Zikmund, 2003). The most common method of data collection in survey research is the structured questionnaire administered to a sample of respondents (Brownell, 1995). As the number of sample industries selected for this study are large, the mail survey has been adopted as it allows a large enough sample to reduce sampling error to acceptable levels, at considerably lower cost, and provides no opportunity for interviewer bias compared to face-to-face and telephone interviews (M. Smith, 2003). However, it is noted that there is no “best” method of survey (Zikmund, 2003). Each method has its own advantages and disadvantages. However, based on the above arguments, a mailed structured administered questionnaire has been adopted in this study. Besides that, this method also allows respondents to answer questions when they are free, require short time periods for surveying large samples than personal or telephone interviews, and the anonymity of the questionnaires permits respondents to be more candid, so making the results potentially more valid and reliable (Cooper & Schindler, 2001). The major weakness of the mail survey is non-response error. Non-response error is the statistical difference between a survey that includes only those who responded and a perfect survey that would also include those who failed to respond.

3.2.5 Interviews

There are a number of methods that can be used to carry out qualitative research, one of these being in detail interviews with members of the teams on which the research is based and the companies being focused upon. The purpose of the interview is to explore the ideas of the interviewees about the phenomenon of interest. There are three basic methods for collecting qualitative data through personal interviews and these are informal conversational interview, standardized open ended interview and in depth
interviews (Patton, 2002). Informal conversational interviews are open and adaptable to the interviewee where no predetermined questions are asked.

Open-ended questions allow interviewees to respond freely to answers and to provide further information rather than just one sentence answers. In-depth interviews can offer rich and in-depth information about the experience of individuals. It must also be recognized that many interview questions can be quite difficult to answer and investigators should perform a thoughtful analysis of all the possible methods that can be used to answer the research question asked.

3.2.6 Case Study

The case study is a systematic research method used to investigate phenomenon deeply within the context of their natural surroundings. Case studies focus on recitation an explicit condition and relationships in that state of affairs usually within an organization. Researchers relate an assortment of method of data collection to gather well-off, detailed information on event, activities, and processes from one or more individuals over a particular period of time (Benbasat et al. 1987; Yin, 1994).

At the start of a case study, the restrictions of the occurrence are not specified and the study begins with the researchers identifying research questions. One of the most important strengths of case studies is that reality is captured in great detail and more variables can be analyzed. However, case studies commonly target a small number of respondents, thus limiting their reliability when generalizing from the small sample to the overall population (Stapleton, 2001). An additional drawback related with the small sample size of case studies is the high risk of producing misleading results (Wall, 2003).
3.3 QUESTIONNAIRE DESIGN

A structured questionnaire has been developed from existing instruments to enhance the validity and reliability of the measures. The questionnaire covers all the technical and managing vicinity. They are:

- Competitive priority.
- Competitive strength.
- Automation implementation.
- Advanced manufacturing technologies.
- Advanced management systems.
- Organizational performance.

In designing the questionnaire, several factors have been taken into consideration, particularly time taken to complete the questionnaire, appropriate person to answer the questionnaire and the words used in the questionnaire. A cross sectional survey approach has been conducted where information has collected at one point in time. In this survey approach, a questionnaire is an instrument used to measure reality ‘dispassionately’ (Creswell, 1994).

The questionnaire used in this study incorporates inputs from various sources: most of the questions have been adopted from previous published work and then the preliminary drafts of the questionnaire has been discussed with academic scholars and practitioners and subsequently tested in manufacturing industries to assess the content validity. The feedback from the above parties has been used to improve the lucidity, fullness and relevance of the research instrument.
It is important to take into high consideration questions format and scaling in turn to produce accurate and meaningful data. There are two types of commonly used question formats: open-ended and closed questions. Open-ended questions permit respondents to answer them in any way they choose, while closed questions require respondents to make options among a set of alternatives given, thus helping the respondents to make quick conclusions (Sekaran, 2003). As for this study, the main scaling format used was closed questions, mainly using Likert-scales. However, the open-ended format was also utilized for the purpose of collecting the respondents’ opinion on the items that were included and/or not included in the questionnaire. This is essential in order to ensure that the collected data are appropriate for the hypotheses testing. The four types of scales are nominal, ordinal, interval and ratio. A nominal scale is the simplest type, where the numbers or letters assigned to objects serve as labels for identification or classification. An ordinal scale arranges objects or alternatives according to their magnitude in an ordered relationship. For the interval scale, it not only indicates order, but also measures order (or distance) in units of equal intervals. The ratio scale has absolute rather than relative’s quantities. The selection of scales was based on information requirements, the goal of survey, ease of development and administration, and the data analysis procedures. Likert-scales have been used to measure changes in competitive surroundings, manufacturing technology.

3.4 SELECTED METHODOLOGY

Esterby Smith et al., (1997) define a research methodology as being a combination of techniques used to enquire a specific situation. At this stage, it has been established that an interpretive philosophy should be suitable for this research study. The methodology used will quantitative research with case study involving manufacturing industries where comprehensively will examine understanding of human behavior regarding manufacturing and the reasons that govern such human behavior.
3.5 REASON FOR CHOOSING CASE STUDY METHOD

The main motive for deciding to carry out a case study is because it is an intensive study of a specific context and it will help to gain more understanding of the activities involved in manufacturing industries which help it to be a success or failure in its given environment. Case based research is a practical enquiry that investigates a present day phenomenon with a real life context when the boundaries between phenomenon and context are not clearly understood (Brannick, 1997).

Yin (1994) contends that the case study approach is appropriate for organizational and management studies. In organizations experiencing rapid change, statically generalizations might be out of date by the time they are unraveled whereas a description of the processes might be valuable.

3.6 REASONS FOR IN DEPTH INTERVIEWS

In depth interviews are chosen as the means to put into operation the primary research in this case study. According to Cooper and Schindler (1998), advantages include a superior depth of information and detail can be obtained when compared to other methods. The researcher has more suppleness to improve the quality of the information received than with any of the other methods also. Interviewers can look for supplementary questions and gather additional information through observation. Esterby et al., (1991) claim that interviewing has often been described as “the best” in order to accumulate information. In addition, a supplementary motive why this approach has been chosen for this research is its appropriateness to gather data with this complex issue and the time constraints imposed for writing a master dissertation.
3.7 CRITICISMS OF QUALITATIVE RESEARCH

The qualitative research can be used as research methodology for this study but there must be some limitations to be wary of when carrying out qualitative research. Aaker et al., (1998) argue that it is not so much the qualitative procedures that have limitations but more the fact that results are often misused and not projected to represent the population as a whole. The reliability of information retrieved can also be questionable.

Silverman (2000) argues that when interviews are carried out on tape, and then transcribed on to paper some valuable communication insights such as pauses or overlaps from the interviewee can be left out, therefore tumbling the reliability of the information repossess. Also qualitative research can be time consuming and expensive with data obtained being hard to interpret.

3.8 MANUFACTURING STRATEGY

The questionnaire compete information on the type of manufacturing strategy has been analyzed. Manufacturing strategy is measured by adapting the empirically tested and validated measures as used by Robb and Xie (2003). Respondents are asked to indicate the importance of the manufacturing priorities in order to compete effectively with their competitors. These items used to operate four competitive priorities, namely quality, flexibility, cost and delivery.

(a) Cost Strategy

Under the dimension of cost strategy, companies compete directly on price, thus cost will be their major operations goal. The lesser the cost of producing their goods and services, the lesser can be the worth to their customers.
(b) Quality Strategy

Quality means ‘doing thing right’ (Slack et al, 1995) and it varies for different types of operations/ business. The quality strategy would lead to customer satisfaction and internal aspect to it leads to a stable and efficient organization. Under the quality dimension of manufacturing strategy, companies were emphasized on three measures, i.e. providing reliable products, high performance products and products with zero defect error.

(c) Flexibility Strategy

Companies pursuing a flexibility strategy offer a wide range of products, excellent after-sales service; customized products, new models introduced to their existing products, new product lines and also produce according to the quantity required. The mean score of the flexibility strategy can be achieved by summing up the six constructs that are used to measure the strategy, i.e. wide range of products, excellent after sale service, customized products, new models introduced to their existing products, new product lines, and also to produce according to the quantity required.

(d) Delivery Strategy

Delivery is regarding how long customers have to wait to receive their products for services. Industries competing on delivery strategy can compete on dependability, i.e. on time delivery and quickest to reach their customers, i.e. speed of delivery.

3.9 ADVANCED MANUFACTURING TECHNOLOGIES

The study investigates the types of advanced manufacturing technologies (AMTs) which are commonly used by manufacturing industries. These technologies can be classified according to their functionalities.
- Advanced design and engineering technologies (ADET)
- Advanced planning technologies (APT)
- Advanced material handling technologies (AMHT)
- Advanced machining technologies (AMcT)
- Advanced management systems (AMS)
- Advanced process improvement systems (APIS)

Industries were asked to indicate the amount of investment by the industries in the individual technology, on a Likert scale of 1-5, where 1 indicates little investment, 3 as moderate investment and 5 to show heavy investment. Industries were determined to be either users or non-users of each technology sub group. For example, an adopter of the design and engineering technology sub group would be using a combination of either CAD, CAE, GT, CAM or all the above.

3.9.1 Advanced Design and Engineering Technologies (ADET)

Manufacturing industries have invested in various design and engineering technologies (ADET), such as computer aided design (CAD), computer aided engineering (CAE), computer aided manufacturing (CAM), and group technology (GT) to assist them in designing and testing a product, from a structural or engineering point, controlling of manufacturing machinery, and also for part classifications and coding systems.

3.9.2 Advanced Planning Technologies (APT)

Manufacturing industries have invested in various production planning technologies (APT), such as material requirement planning (MRP), Manufacturing resources planning (MRP II), and Enterprise resources planning (ERP) to assist them in planning, scheduling and controlling of
material and resources requirements for the production of manufacturing companies. ERP covers a wider scope by integrating the operations throughout the companies and also facilitates global integration.

3.9.3 Advanced Material Handling Technologies (AMHT)

Material handling technologies (MHT) are AMTs used by manufacturing industries to facilitate the handling of material in manufacturing operations. Automated storage and or retrieval systems (AS/RS) use computers to direct automatic loaders to pick and place items for production processes or storage by automatic high lift trucks. Industries employ transport automation by using automated guided vehicles (AGVs) to move materials to and from value adding operations.

3.9.4 Advanced Machining Technologies (AMcT)

The study observes the level of investment in types of assembly and machining technologies: Flexible manufacturing system, computer aided control system, robotics and numerical control machines (NC/CNC/DNC). These AMTs are used to perform repetitive functions and work without permanent alteration of the equipments. FMS is capable of multiple paths, and may also be comprised of two or more linked in series or parallel. Robotics to carry out various operations like handling, process or assembly tasks, whilst numerical control machines exist for almost all types of machining, like turning machines, boring and milling machine, horizontal boring machines and machining centers.

3.9.5 Advanced Management Systems (AMS)

The study observes the level of investment in advanced management systems. Total quality management (TQM) can be summarized as a management system for a customer-focused organization that involves all employees in continual improvement. Business process re-engineering (BPR) is basically
rethinking and radically redesigning an organization's existing resources. SPC is applied in order to monitor and manage a process. Monitoring and controlling the procedure ensures that it operates at its full potential. Just in time is simple the storage of unused inventory is a waste of resources. The JIT inventory philosophy defines how inventory is viewed and how it relates to management.

3.9.6 Advanced Process Improvement Systems (APIS)

Advanced process improvement systems are benchmarking, recycling, kaizen and management training. Benchmarking is the process of comparing one's business processes and performance to industry best or best practices from other industries. Recycling is a process to change waste into new products to prevent waste of potentially valuable materials, lessen the utilization of fresh raw materials, and reduce usage. Kaizen is used for improvement for the better or practices that focus upon continuous improvement of processes in industrialized, engineering, and production management.

3.10 OVERALL RESEARCH DESIGN AND METHODOLOGY

As mentioned before, the questionnaire has been based on the recent developments in the subject and has been designed after a thorough study of international literature. Its structure contains different sections, each addressing separate concerns. A brief explanation of each section of the questionnaire is given below, while the full questionnaire is shown in Appendix.

Section A: General Characteristics of the Industries:

This section contains questions which aim to extract information of manufacturing industries, in detail it yields information on:

- The types of products and services of the industries
• The number of human resources and yearly sales.

• The manufacturing characteristics and

• The production plant characteristics

**Section B: Manufacturing strategy:**

This section includes the manufacturing strategy of the industries. In particular it investigates the following strategies;

• Competitive priority

• Competitive strength

• Manufacturing strategy strength

• Automation implementation steps

**Section C: Advanced manufacturing technology:**

This section examines the level of investment in advanced manufacturing technologies. These technologies can be classified according to their functionalities.

• Advanced design and engineering technologies (ADET): CAD, CAM, CAE, GT

• Advanced planning technologies (APT): MRP, MRPII, ERP,

• Advanced material handling technologies (AMHT): AGV, AMHS, AS/RS

• Advanced machining technologies (AMcT): NC, CNC, DNC,

• Advanced management systems (AMS): TQM, JIT etc.
Advanced process improvement systems (APIS): Benchmarking, Kaizen, etc.

Section D: Industries priority:

This section examines the industries priority for environment, quality, market etc. In detail the following are addressed:

- The environment friendly activities
- The order winning criteria
- The ISO Certification
- The world class industrialized actions

Section E: Results after adoption of AMTs:

This section includes the performances of the manufacturing industries after adoption of advanced manufacturing technologies. Specifically, it indicates the following effects:

- Productivity
- Plant efficiency
- Production management
- Manufacturing performance

The questionnaires have been managed by post together with a covering letter to 240 industries. The letter was addressed to the directors or managers of the industries.
3.10.1 Statistical Analyses

This section looks at the statistical techniques used to analyze data collected from the questionnaire. The first part of the section explains the correlation technique, and the last part of the section looks at the analyses techniques and hypotheses testing used to measure.

3.10.2 Hypotheses Testing

There have been hypotheses derived from literature:

Null Hypothesis (H₀): The level of investment in advanced manufacturing technology is same in different manufacturing industries.

Alternative Hypothesis (H₁): The level of investment in advanced manufacturing technology is different in different manufacturing industries.

Null Hypothesis (H₀): The performance of manufacturing industries is increased by advanced manufacturing technology.

Alternative Hypothesis (H₁): The performance of manufacturing industries is decreased by advanced manufacturing technology.

The information for the statistical analyses has been collected via a questionnaire completed by the informant in the surveyed company, mainly from the top management team. The information consists of the type of manufacturing strategy orientation, type of AMT and their perceived performance in regards to their manufacturing capabilities.

The intend of the hypotheses testing of the study is to test the level of investment in advanced manufacturing technologies and the diffusion of AMTs to facilitate the manufacturing processes in order to achieve the intended manufacturing performance.
A correlation, or bivariate correlation, measures the relationship between variables. The correlation measures the strength of the relationship, which ranges from -1 to +1: the closer the correlation is to 1 or -1, indicates a strong relationship, whilst the closer the correlation is to 0, the weaker the relationship. Cronbach’s coefficient alpha is used to assess the internal consistency of the measures for each construct. Cronbach’s alpha has the highest utility for multi-item scales at the interval level of measurement (Cooper & Schindler, 2001).

It is then followed by further tests to examine whether the samples are normally distributed in order to make meaningful inferences. This can be achieved by conducting a normal graph. After which, the hypotheses testing have been performed by testing the level of agreement between the variables by examining F test of advanced manufacturing technology.

In terms of the measurement of AMT, the score of each of the six categories is derived based on two distinctive measurements: the level of investment and the extensiveness of its performance. The mean score of each type of AMT is calculated by taking the average of its investment score. Therefore, six measurements of AMT have been observed, which are Advanced Design and Engineering Technology Score (ADT), Advanced Planning Technology Score (APT), Advanced Material Handling Technology Score (AMHT), Advanced Machining Technology Score (AMcT) and Advanced Management System Score (AMS). Advanced Process Improvement System Score (APIS).

The manufacturing performance of different industries has been determined by their productivity, product managements, plant efficiency and overall efficiency. Manufacturing performance of industries has been analyzed by hypotheses testing. The main reason for deciding to carry out a case study is because it is an intensive study of a specific context and it will help to gain more understanding of the activities involved in manufacturing which help it to be a success or failure in its given environment.
3.11 CONCLUSION

This chapter provides the methodology applied for the research problem. The design is based on established research practices and through pretesting. The mail survey has been sent to manufacturing industries and generates a usable response rate. This study attempts to provide answers of research questions by examining technology. The study focuses on the competitive priority of industries, level of investment on advanced manufacturing technology, their manufacturing performance and efficiency enhancement of manufacturing industries through the advanced manufacturing technologies. Some case studies have been taken from manufacturing industries and after implementation of advanced manufacturing technology performance have been investigated.