QUALITY ASSURANCE PRACTICES BY INDIAN MANUFACTURING ORGANIZATIONS: A CONCEPTUAL FRAMEWORK AND AN EMPIRICAL INVESTIGATION

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The purpose of this study is three-fold. First, based on the synthesis of literature on quality concepts, critical factors that must be practiced to achieve effective quality management in an organization were identified. A framework to be used by organizations to evaluate their quality assurance practices was developed. Second, a field survey was conducted to identify the degree to which quality assurance is being practiced in Indian manufacturing organizations and to locate the organizational areas where better management control can make the quality assurance system more effective. Finally, an attempt was made to develop models that could be used to forecast the level of quality achieved.

For the purpose of identifying critical factors, the quality philosophies of earlier researchers were assimilated. Through a judgmental process of grouping similar requirements, it was found that all the requirements for effective quality management could be classified into the following nine major critical factors: (1) top

management, (2) quality policies, (3) role of the quality department, (4) training, (5) product design, (6) vendor quality management, (7) process design, (8) quality data, and (9) feedback and employee relations.

To measure managers' perceptions about quality management practices in Indian organizations, an existing validated instrument was utilized. Only manufacturing organizations employing more than 500 employees, with a total sales volume of over 251 million rupees, were included in the sample since it was thought that the quality management practices of these organizations were likely to be more sophisticated. Seventy-three organizations participated in this study.

The overall conclusion that emerged from this study was that, contrary to what was hypothesized, it is not necessary for all factors to be present to insure the success of the total quality program of the organization.

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CHAPTER I

INTRODUCTION TO THE STUDY

During the past decade, managerial concern for quality reached unprecedented levels. Today, an increasing number of managers in more organizations than ever before view "quality as of bedrock strategic importance, rather than an abstract to be pulled out of the platitudes file and given lip service at the annual general meeting" (Guaspari 1987). Research has confirmed the strategic benefits of quality. Quality has been shown to contribute to greater market shares and return on investments (Cole 1983; Phillips, Chang, and Buzzell 1983) as well as lower manufacturing costs and improved productivity (Garvin 1983). The quality of a firm's products, the prices it charges, and the supply it makes available are all factors that determine demand. In today's technological age, quality is an international as well as corporate concern. For example, consumers are increasingly concerned about the quality of goods and services they buy (Barksdale et al. 1982; Center for Policy Alternatives 1978; New York Times 1983). For a company or country to compete effectively in the global economy, its products must meet a certain standard of quality.

Distribution of inferior products can harm firms and nations, both at home and abroad, and can have severe implications for balance of payments (Scagoline 1988). In India, too, industrial and service organizations are becoming concerned with the need to upgrade the quality of their products and services inorder to keep pace with competition within and outside the country (Chellaney 1990).

Purpose of the Study

The purpose of this study is three-fold. First, based on the synthesis of literature on quality concepts, critical factors that must be practiced to achieve effective quality management in an organization were identified. A framework to be used by organizations to evaluate their quality assurance management practices was developed. Second, a field survey was conducted to identify the degree to which quality assurance is being practiced in Indian manufacturing organizations and to locate the organizational areas where better management control can make the quality assurance system more effective. Finally, a method using multiple regression analysis was developed that can be used by organizations to forecast quality.

Statement of the Problem

In this research, two main issues are addressed. The first, is a need for further empirical research in the field of quality management practices; only two major empirical studies (Garvin 1984; Saraph, Benson, and Schroeder 1989) could be located. The second issue pertains to the identification of the most influential factors that affect prediction of quality. The literature review gave no indications that any previous study had addressed this issue.

Significance of the Study

Identifying and measuring the critical factors of quality management can be very useful. Managers can use the critical factors to (1) obtain a better understanding of quality management practices, (2) determine the current quality position of an organization, (3) assign responsibilities within an organization, and (4) monitor quality and improvement programs (Motwani, Sower, and Rosenfeldt 1989). Decision makers can thus isolate the critical factors that are necessary for organization-wide improvements in quality environments (Saraph, Benson, and Schroeder 1989). Researchers can use the critical factors to build theories and models that relate these factors to the quality performance and quality environment of an organization. The empirical field study conducted in India to assess the practices and attitudes concerning quality (1) tested the reliability and validity of the instrument developed by Saraph, Benson, and Schroeder (1989) in an international environment, (2) established priorities for the quality assurance factors, (3) developed an adequate data base for future cross-cultural comparisons, and (4) provided guidelines to Indian manufacturing organizations for planning and organizing effective control of their quality assurance functions. This will not only help to increase the quality of their products and services and reduce costs but also help to utilize more effectively the available resources of raw materials, equipment, and manpower. Finally, forecasting quality helps policy-makers to plan better by pinpointing important variables affecting the level of quality and also the magnitude by which these variables affect the level of quality.

Definition of the Terms Used

The following terms are defined for use in this study:

Quality. A number of definitions, some of which are ambiguous, exist for the word quality. Garvin (1984) categorized five definitions of quality. For the purpose of this study, the following four are used: (1) Product-based definition: Quality refers to the degree or quantity of some attribute contained within the product (Leffler 1982); (2) User-based definition: Quality refers to the degree to which a product satisfies customer wants (Gilmore 1974; Juran 1981); (3) Manufacturing-based definition: Quality means conformance to the required specifications (Crosby

1979), and (4) Value-based definition: Quality refers to providing a product with acceptable quality at a reasonable price (Broh 1982, Feigenbaum 1983). All four definitions are valuable and necessary and must be considered together to strengthen the competitive position of the firm (Garvin 1984).

Quality assurance. The term quality assurance is coined to describe a firm's concern and commitment when the concept of quality is applied to various aspects of organizational behavior, activities, and functions. Quality assurance applies to the design of products and services, the processes or procedures selected to achieve design specifications, and the policies, strategies, and procedures chosen to design and monitor quality (DelMar and Sheldon 1988).

Statistical quality control is an important component of quality assurance. The scope of statistical quality control is limited to the measuring, evaluation, and decision making involving only a few aspects of a firm's composite concern for quality.

Quality management. According to Juran (1974), quality management is the totality of ways through which an organization can achieve quality. In other words, quality management includes all three processes of the quality trilogy: planning, control, and improvement.

Total quality control (TQC). TQC is an effective system for integrating the quality-development, quality-maintenance, and quality-improvement efforts of various groups within an organization so as to enable production and service at the most economic levels which allow for full customer satisfaction (Feigenbaum 1976).

Background Research

Much of the literature on quality focuses on the following areas: Japanese quality management practices (Juran 1978, Schoenberger 1982); the development of organization-wide quality improvement programs (Crosby 1979); the application of various statistical quality control techniques (Deming 1981, 1982, 1986; Gitlow and Hertz 1983; Wood 1981); the concept of organization-wide and total quality control (Feigenbaum 1983) and the importance of critical factors such as top management leadership, process management, employment training, and employee involvement in quality (Feigenbaum 1976; Langevin 1977; Reddy and Berger 1983; Snee 1986, Takeuchi and Quelch 1983). These studies have basically outlined steps to be followed in correcting problems with quality. Garvin (1984) and Saraph, Benson, and Schroeder (1989) are the only two studies, based on the review of literature, that have carefully identified and analyzed the causes of quality problems. Therefore, these two studies form the background for this research.

In 1984, Garvin conducted an exploratory study to determine the causes of quality problems and the contributors to quality performance in the United States and Japan. This study drew on surveys of first-line supervisors of the airconditioning manufacturing industry. It focused on (1) the changing mix of organizational problems as performance improves, and (2) the relationship between managements policies, workers attitudes, and performance.

Nine United States companies and seven Japanese companies participated in the study. The results indicated that United States and Japanese manufacturers not only faced different profiles of quality problems, but were also approaching the task of quality management quite differently. According to supervisors, Japanese firms displayed a strong management commitment to quality, organized their thinking around process control and production management, and reduced prevailing levels of rework and scrap. Although these companies still faced certain quality problems, primarily in the area of product design and purchased parts and materials, supervisors believed that most of their problems arose outside the shop floor. By contrast, United States supervisors attributed the largest proportion of their firms' quality problems to deficiencies of the workforce or workmanship. More specifically, a deep concern for quality was thought to be lacking among workers and managers, even though supervisors were frequently evaluated on such measures as defect and scrap rates. Overall, United States supervisors believed that quality was a secondary or tertiary objective for manufacturing, lagging well behind the primary goal of meeting production schedules.

Saraph, Benson, and Schroeder (1989), on the other hand, provided a synthesis of the literature on quality by identifying critical factors (areas) of quality management in a business unit. A comprehensive set of eight critical factors was proposed. Operational measures of these factors were developed using data collected from 162 general managers of 89 divisions of 20 companies located in the Minneapolis/St. Paul area. The measures could be used individually or in concert, to produce a profile of organization-wide quality practices. The measures proposed were empirically based and shown to be reliable and valid.

Research Questions

A review of related literature suggested the following major research questions:

1. What are the major manufacturing objectives of Indian organizations? How does top management rank these objectives?

2. Do Indian manufacturing organizations have their own quality departments? What role does the department play?

3. What are the major causes of quality problems faced by Indian manufacturing organizations?

4. Do organizations employ a quality cost reporting system? What are the major components of the total cost of maintaining quality?

5. Are there suitable training programs for the purpose of enhancing the effectiveness of quality assurance?

Preview

In the following chapter, a selective review of literature relevant to this study is presented. In Chapter III, the research methodology and procedures for data collection are described. The results of the research and findings are delineated in Chapter IV.

The final chapter provides an interpretation of the findings of this research project and their implications. It also contains conclusions and suggestions for future research.

CHAPTER II

REVIEW OF LITERATURE

Relevant material found in the literature dealing with quality is discussed in this chapter. The literature on quality contains numerous articles and books on how quality should be managed in an organization. The volume of material, as well as the diversity of the subject matter, makes it impossible to present an exhaustive presentation of the topic. Therefore, only pertinent material most relevant to this research project has been included. The primary focus of the chapter is the identification and explanation of the critical factors that organizations need to consider when implementing a quality assurance program.

Quality Philosophies

How quality assurance is implemented in an organization is a matter of philosophy. Several popular philosophies prevail today. For the purpose of identifying critical factors, the philosophies of quality experts such as Deming (1981, 1982, 1986); Juran (1974, 1978, 1981, 1986a, 1986b, 1988, 1989); Crosby (1979, 1989); Ishikawa (1976, 1988); and Feigenbaum (1961, 1983, 1985, 1986, 1989) will be addressed in this chapter.

Edward Deming

W. Edward Deming is credited with institutionalizing a system of strategic manufacturing which is responsible for the formidable Japanese presence in the world market. Deming stressed the necessity of top management involvement, attention to customers' needs, involvement of all employees in the process of continual improvement, and the need to pay close attention to the entire manufacturing process as keys to corporate success (Mann 1988, Scherkenbach 1988). He intimated that 85 percent of the causes for poor quality production rested with management, and not with workers (Baillie 1986).

Deming's philosophy of strategic manufacturing goes far beyond the use of statistical methods. His concept of the manufacturing process encompasses all parts of the organization as well as constituencies outside the organization. Deming advocates creating an outstanding product at lower cost which will provide real growth for the organization. President Bush reflects Deming's philosophy when he says "competitiveness . . . (does not) mean protectionism . . . (but) trying to improve quality and productivity at home" (Kendrick 1988).

Deming's philosophy expands the definition of an organization's process from the traditional manpower, methods, materials, and machines to include suppliers, customers, investors, and the community (Deming 1986; Gitlow and Gitlow 1987). The customer is the most important part of this extended process.

The fourteen points comprising Deming's philosophy are designed to improve all aspects of manufacturing. These points comprise a systems approach to improving the competitive position of United States manufactured goods in the world market. According to Deming, management must take the following action (Tribus 1988; Walton 1987):

1. Create a constancy of purpose toward improving products and services and plan products with a view toward the long-range needs of the company.

2. Adopt the new philosophy that no company can compete in the world market until its management discards old notions about the acceptable level of mistakes, defects, and inadequate training and supervision.

3. Eliminate dependence of mass inspection of quality and use statistical controls to ensure that quality is built into the product or service.

4. Reduce the number of suppliers by awarding business based on quality and not on price alone.

5. Recognize that there are two sources of quality problems--faulty systems and the production worker. Management's job is to improve the system continually

through design, purchasing decisions, maintenance, training and supervision.

6. Institute modern methods of job training focused on prevention of errors and defects.

7. Provide a higher level of supervision. Supervisors must set examples, assist workers, and provide training.

8. Drive out fear by encouraging open, two-way communication so that everyone works effectively for the organization.

9. Break down barriers between the departments and promote cooperation.

10. Eliminate numerical goals and slogans that seek improvements without providing methods.

11. Eliminate work standards that provide numerical quotas.

12. Remove barriers that hinder hourly workers and their right to pride of workmanship.

13. Institute a vigorous training program to polish current skills and to learn new methods and techniques.

14. Finally, top management and all supervisors should push every day to see that the previous 13 points are carried out.

Joseph Juran

Along with Deming, Juran is considered one of the early leaders in the field of quality. Juran taught quality principles to the Japanese in the 1950s and was a principal force in their quality reorganization. Juran is famous for developing the Juran Trilogy, as a new model of strategic quality management (Juran 1974, 1978, 1981). His trilogy states that managing for quality entails three quality-oriented processes: (1) quality planning and the annual quality program, (2) quality control and the control sequence, and (3) quality improvement and the breakthrough sequence. According to Juran, the control sequence is designed primarily to attack Deming's special causes, the breakthrough sequence attacks common causes, and the annual quality program institutionalizes managerial control and review over the quality management process (Juran 1986, 1988).

Fundamental concepts in Juran's philosophy include: (1) a great need for competent companywide quality management, (2) senior management must play an active and enthusiastic leadership role in the quality management process, (3) training must be provided in the major managerial quality-oriented concepts, and (4) at every point in time, hundreds or even thousands of quality improvement projects should be way under in every area where improvement is desirable.

Juran founded the Juran Institute in Wilton, Connecticut, to spread the idea that improvements must begin with commitment from top management and that improvement programs must be built into a company's total operating philosophy (Urrows and Urrows 1986).

Juran's approach is credited with the success of an expanded quality control system at Owatonna Tool that brought savings of more than $2 million, production increases, and better communications. Similarly impressive results have come from using the Juran approach at Textronix, GTE Network Systems, General Motors of Canada, and a host of other companies.

Philip Crosby

Crosby, like Deming and Juran, is also one of the leaders in the quality movement. Crosby is a chief proponent of the notion that quality is free. The essence of Crosby's quality involvement process is embodied in what he calls the Absolutes of Quality Management and the Basic Elements of Improvement. The follwing are Crosby's Absolutes of Quality Management:

1. The definition of quality is conformance to requirements. Conformance to requirements is achieved by doing it right the first time. To accomplish this, production and its loopholes must be understood thoroughly and that requirement should be the responsibility of management. The Crosby school of thought leans heavily on the idea that top management must not only be committed to

quality, but must set the tone and pace for implementation of quality throughout the organization. Management must "insist on conformance to requirements and provide the participation necessary for prevention to happen" (Crosby 1979).

2. The system for causing quality is prevention. The first step toward prevention is to understand the production process. Once this is done, the objective is to discover and eliminate all opportunities for error. Statistical methods are useful in this regard.

3. The performance standard is zero defects. Crosby feels that this is widely misunderstood and resisted. He claims that many people accept zero defects as a standard in many aspects of their personal lives and need only to be convinced that zero defects is a reasonable and essential standard in their work lives.

4. The measurement of quality is price of nonconformance. Quality cost data are useful to make management aware of quality problems, select opportunities for corrective actions, and track quality improvements.

Crosby's Basic Elements of Improvement include determination, education, and implementation. Crosby places more emphasis on management and organizational processes for changing corporate culture and attitudes than on the use of statistical techniques as advocated by Deming and Juran.

Kaoru Ishikawa

Ishikawa (1976) is popular for his emphasis on the concept of total quality control. According to Ishikawa, the quality function is the responsibility of all departments. Training foremen and employees to improve quality, and active involvement in employee participation programs such as quality circles, are essential ingredients of a successful quality assurance program.

He is also popular for advocating the cause-and-effect diagram (sometime called the Ishikawa diagram) to diagnose quality problems. It is a simple, graphical method for presenting a chain of causes and effects for sorting out causes and organizing relationships between variables. Cause-and-effect diagrams are constructed mainly in a brainstorming atmosphere where small groups, usually drawn from manufacturing or management work with a trained and experienced facilitator. As a group technique, the cause-and-effect method requires significant interaction between group members; thus, a good facilitator is important for success.

Armand Feigenbaum

Though Ishikawa emphasizes total quality control, Feigenbaum is popular for introducing the concept of total quality control. According to Feigenbaum (1983), "In every organization, effective quality management must be a total, companywide effort that is aimed at the avoidance of problems through the planning and engineering of products, processes, and methods; the identification of problems that inevitably will arise; correction of these problems; and continuous improvement of quality performance."

The only way for corporations today to meet domestic and international competition head-on is for leaders to manage the business in terms of international quality leadership. Feigenbaum suggests the following seven keys to constant quality as the basis for this commitment (Feigenbaum 1989):

1. A manufacturer must meet the buyer's requirements for quality.

2. A customer-oriented quality management system works only when all the persons in the organization understand it and believe in it.

3. Quality is a system that extends throughout an organization.

4. The quality process must generate pervasive improvement throughout an organization.

5. Quality requires application and integration of the latest technology.

6. Quality is not guaranteed by automation and robotics.

7. High quality and low costs are partners, not adversaries.

The Japanese have adopted Feigenbaum's concept and have strongly emphasized total quality control. They have used the concept very successfully to compete in world markets.

From the literature review several organization requirements for effective quality management are generated. All the requirements can be classified into the following nine major critical factors: (1) top management, (2) quality policies, (3) role of the quality department, (4) training, (5) product design, (6) vendor quality management, (7) process Design (statistical quality control), (8) quality data, and (9) feedback and employee relations. Each of these factors is supported by all or nearly all of the authors in their philosophies as shown in Table 1 (see Saraph, Benson, Schroeder 1989). When combined, these factors define the important aspects of quality management practice. The nine critical factors identified are explained in Table 2. The entire model developed for the purpose of this study is illustrated in Figure 1. The model presents, in a single schematic diagram, the dependent and independent variables that relate to quality assurance practices in organizations.

Table 1.--Organizational Requirements for Effective Quality Management

Concepts	Deming	Juran	Crosby	Ishikawa	Feigenbaum	Garvin	Saraph
Top management	X	X	X		X		
Quality policies	X	X	X		X	X	X
Role of the quality department	X	X	X	X			X
Training	X	X	X	X	X		X
Product design		X	X		X	X	X
Vendor quality management	X	X				X	X
Process design (statistical quality control)	X	X	X	X		X	X
Quality data	X	X	X	X		X	X
Feedback and employee relations	X	X	X	X	X	X	X

Table 2.--Identification and Definition of Quality Factors

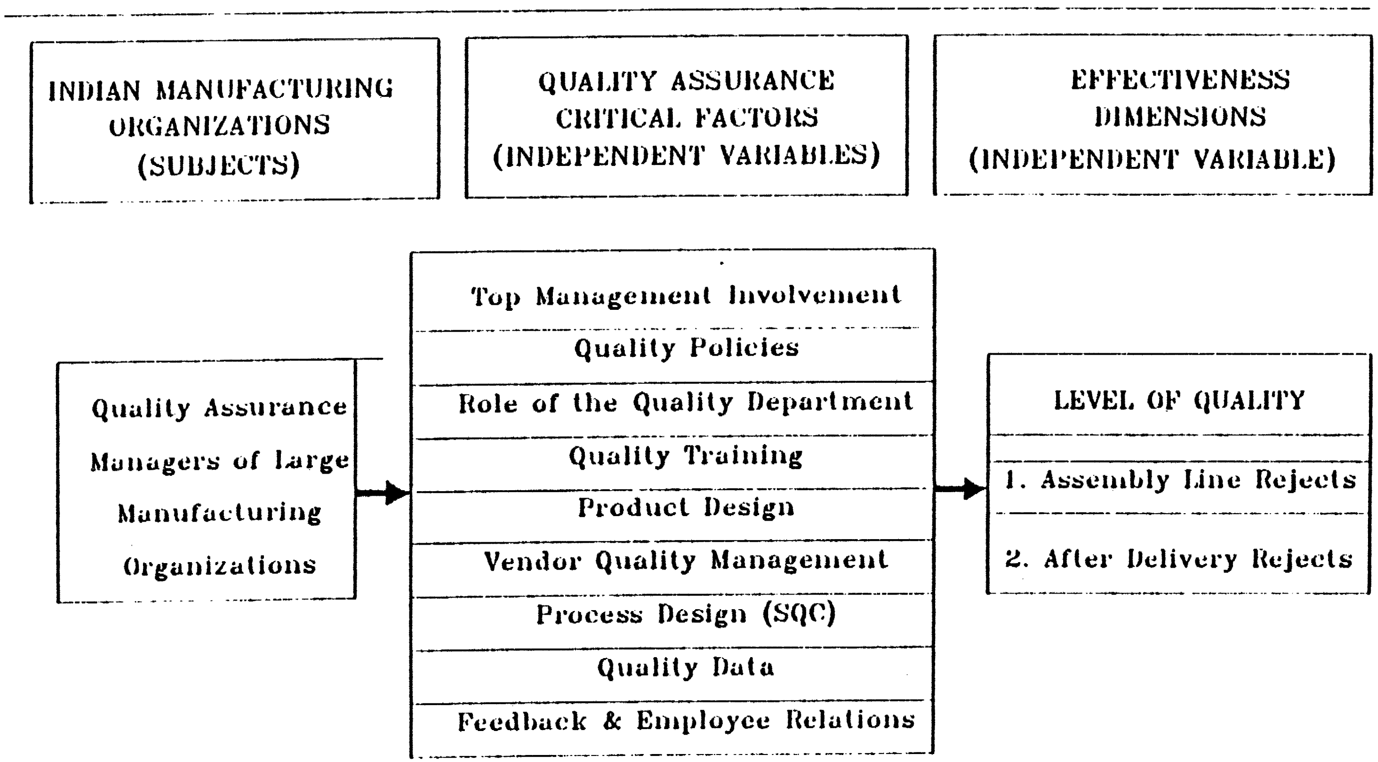
Factors	Definition	Source
Top management	Participation of top management in quality improvement efforts. Top management initiative, philosophy, and support is essential for a successful quality assurance program.	Crosby 1979; Deming 1986; Feigenbaum 1986a, 1986b
Quality policies	An organization's policies and programs are the practical embodiment of its attitudes toward quality. Quality policies give substance to more ethereal attitudes and philosophies, providing direction and support.	Garvin 1983, 1984; Juran 1974
Role of the quality department	Every organization should have a visible and autonomous quality department. Proper coordination between quality department and other departments is essential.	Crosby 1979; Ishikawa 1976; Saraph, Benson, and Schroeder 1989
Training	Training includes all forms of planned experiences and activities whose purpose is to change performance and other behavior through acquisition of new knowledge, skill, beliefs, and attitudes. If an organization is to grow and prosper, a formal and quality training program must be developed.	Crosby 1979; Deming 1986; Juran 1974; Mondon 1982
Product design	Quality product design requires involvement of all affected departments in the design review. The design review should emphasize the quality of design and clarity of specifications.	Adam, Hershauer, Rich 1981; Garvin 1983; Juran 1974; Mondon 1982

Table 2. -- Continued

Factors	Definition	Source
Vendor quality management	Working with vendor to improve quality requires a relationship of openness and trust. The single source environment is conducive to pursuing quality improvement.	Adam, Hershauer, Rich 1981; Deming 1982; Juran 1974
Process design	Clarity of process boundaries and steps should exist. Statistical quality control provides means for quality analyzing the process, continually improving the process, and controlling product control quality through quality of the process.	Crosby 1979; Deming 1982; Garvin 1983; Juran 1974; Mondon 1982; Saraph, Benson, and Rich 1989
Quality data	Availability and use of quality cost data and other quality data are essential. The cost of achieving quality must be carefully managed so that the long-range effect of quality cost on the organization's profit is a desirable one. Quality costs can be broken down into 4 main categories: prevention, appraisal, internal failure, and external failure costs.	Crosby 1979; Juran 1974; Mondon 1982
Feedback and employee relations	Feedback regarding the quality program and employee relations relations includes reviewing quality assurance design and performance. Most of all, it involves recognition of quality assurance performance which includes rewards and punishments for compliance and noncompliance. Open employee participation is the key to success.	Adam, Hershauer, Rich 1981; Crosby 1982; Ishikawa 1976; Mondon 1982

Figure 1

A SCHEMATIC MODEL OF THE RELATIONSHIP BETWEEN
QUALITY ASSURANCE FACTORS AND THE EFFECTIVENESS DIMENSIONS



Specifically, the nine critical factors in quality assurance are the independent variables. The effect of these independent variables on the dependent variable, or the level of quality, is measured in terms of the latter's surrogates: assembly line reject rate and after-delivery reject rate. In this model, assembly line reject rate is defined as the percentage of total defects per unit produced. The term after delivery reject rate relates to the percentage of defective items returned by customers and/or that require field service during the warranty period. The independent variables are described in detail in the following sections.

Evaluation of Critical Factors

The critical quality assurance factors identified and defined in Tables 1 and 2 are explained in the following paragraphs.

Factor 1: Top Management

Successful quality performance requires management dedicated to that goal (Crosby 1979; Feigenbaum 1983). Without commitment at the highest levels, such objectives as delivery and cost are assumed to take precedence.

Perhaps the major difference in the philosophy of quality between United States and Japanese manufacturers is in the depth of their top management's commitment to quality. At Japanese plants, the top management's commitment to quality is deeply ingrained and clearly communicated. It is visible everywhere: in statements of company philosophy, policy manuals, and charts and banners on the walls, etc. For example, at Matsushita, quality appears prominently in the company's slogan: "Let us limitlessly supply good quality products to our society, and let us contribute to foster even richer electrified life to our people" (Ishikawa 1988). Japanese managers feel that anything worth doing in the area of quality is worth overdoing. In Japan, most plants set formal quality goals, using a process that normally proceeds from highly general to highly specific targets (Cole 1980). From the corporate level come vague quality pronouncements, which are further defined by division heads and by vice presidents of quality or manufacturing. Actual quantitative goals are set by middle managers or by foremen or workers operating through quality control circles. The above collaborating nature of the process and the progressive narrowing of the goals are not followed by United States organizations. In United States organizations, the quality department is primarily responsible for quality. Tasks are assigned along functional lines and specialization is the rule (Garvin 1984).

Factor 2: Quality Policies

Attitudes and philosophy alone are seldom enough to improve quality. Even though they provide direction and emphasis, supporting structures are necessary. A company's programs, policies, and systems are the practical representations of its attitudes toward quality (Garvin 1983, 1984).

Quality policies of an organization usually (1) declare the intention to meet the needs of the customers--the wording often includes identification of specific needs to be met; (2) include language relative to competitiveness in quality--for example, that the company's products shall equal or exceed competitive quality; (3) relate to quality improvement--for example, the intention to conduct improvement annually; and (4) include specific reference to internal customers--for example, that quality should extend to all phases of the business (Garvin 1983). At IBM there is a quality policy requiring that new models of products must have a reliability at least equal to the reliability of the models they replace, and to the reliability of the models of competitors. The product-development departments are required to demonstrate that this policy has been met. In addition, the quality assurance department has the responsibility to review the demonstration (Juran 1974).

It is the duty of top management to assure that the prevailing quality policies correctly reflect the company's intentions with respect to quality, that is, if the policies are found to be out-of-date, top management should take steps to assure that the quality-policy statements are updated.

Factor 3: Role of the Quality Department

In traditional organizations, the quality department has the primary responsibility for quality. Tasks are assigned along functional lines, and specialization is the rule. Quality is treated no differently from marketing or finance. In such settings, designers, purchasing agents, and production managers are considered peripheral to the quality department, for their responsibilities lie elsewhere.

This approach to quality has serious flaws. Garvin's (1983) study clearly demonstrates that the defect and failure rates are strongly affected by design, vendor management, and production practices. In these areas, the quality department cannot proceed alone.

Extensive research by Ishikawa (1976), Leonard and Sasser (1982), and Mondon (1982) has shown that for the best results, the quality department should have (1) visibility, autonomy and direct access to top management; (2) proper communication and coordination between quality department and other departments, and (3) a quality staff should be used as consultants to solve advanced quality problems.

Factor 4: Training

New employees must be oriented to a company's philosophy of commitment to never-ending improvement, be informed of company goals, and be made to feel a part of the team. Initial training is very important, for it is easier to train an employee properly than to erase the effect of improper training. Workers who receive only on-the-job training cannot be relied upon for top performance. The experienced employee doing the training may not be a good teacher or may leave out an important aspect of the job. Even when such problems do not exist, the trainee receives a narrow view, focused only on the mechanics of the job at hand (Tribus 1988).

Proper training includes explanations of overall company operations and product quality specifications. Where statistical process control (SPC) is practiced, training in statistical methods must be included (Crosby 1979; Deming 1982; Juran 1974). Training workers to achieve statistical control results in improvement of quality. Deming views employees as an organization's most valuable long-term resource. Through training, management can enable employees to flourish and constantly improve. Effective training enables workers to more easily identify with the company and its goals and to feel good about the jobs they do.

Bennis (1987) suggests that American organizations are over-managed and under-led. Deming's seventh point directs organizations to institute leadership in order to remove barriers which prevent employees from taking pride in what they do. Instead of focusing on the negative, management must provide a positive and supportive working environment. In such an environment, workers are open to learning, development, and change.

Supervisors should use statistical tools to determine individual employees' training needs. By properly responding to these needs supervisors can help workers do a better job.

Management is also responsible for eliminating special causes for process variation (Walton 1987). Employees realize that management is serious when it stresses continual improvement and they realize that management is capable of taking the appropriate action to achieve it.

Factor 5: Product Design

Design practices provide an ideal starting point for the study of quality performance. At this stage, everything is in flux. Product requirements are still on paper, components have yet to be determined, and vendors are unspecified. A wide range of possible choices exists. Moreover, changes are relatively simple and inexpensive to make. Once designs are final, the character and functioning of a new product is largely set and several crucial elements affecting final product quality are established.

Surprisingly, the basic steps in the design process are somewhat similar in all industries. New products typically progress through four stages: concept development, engineering prototypes, pilot runs, and production units (Garvin 1984).

Based on the review of literature, the following factors should be considered by an organization when planning for the product design processes: (1) understand fully the customer product and service requirements; (2) emphasize fitness of use, clarity of specifications and producibility; (3) involve all affected departments in design reviews; and (4) avoid frequent redesigns (Adam, Hershauer, Rich 1981; Crosby 1979).

Factor 6: Vendor Quality Management

Purchasing the lowest priced material is frequently synonymous with purchasing the lowest quality material. To make a purchasing decision on the basis of price alone is another example of short-term thinking. Lower quality materials result in production problems and increased defects in manufacturing. Purchasing managers must understand the problems encountered in using purchased materials in order to make better purchasing decisions. Purchasing departments frequently use multiple sourcing as a way to play one supplier against another in an effort to obtain a lower price. Multiple sourcing is also used to prevent disastrous interruption of materials from vendors (Crosby 1989). Careful selection and management of vendors are equally important in the United States and Japan. Supplier relations are also of roughly the same duration. Japanese plants estimate an average of ten years per supplier, while United States plants estimate an average of 12.5 years (Ishikawa 1988). Single sourcing is more widely practiced in Japan, but is not uniform. In Garvin's study, for example, three Japanese plants single-sourced less than twenty percent of their purchased parts and materials, placing them below the American average.

Multiple sourcing creates a short-term, price dependent, inflexible relationship between buyers and sellers (Deming 1982). Single sourcing has as its basis a long-term relationship of trust and mutual sharing of information between buyer and seller. By properly qualifying vendors, using statistical evidence to monitor their quality, and improving communications, a long-term relationship can be established to the mutual benefit of the buyer and the seller (Goetz 1978).

The single source environment is conducive to pursuing continual quality improvement. Working with vendors to improve quality requires a relationship of openness and trust with statistics as the common language.

Factor 7: Process Design (Statistical Quality Control)

All quality controls must start with the process itself. The first step is to identify the critical points in the process where inspection is needed. There are basically three critical inspection points (Deming 1986).

1. Inspecting incoming raw materials to ensure vendor compliance with raw-material specifications. This inspection constitutes a screening process whereby defective materials are returned to the vendor and acceptable materials are passed on to the production.

2. Inspect work in process or the service while it is being delivered. As a general rule, the product or service should be inspected before irreversible operations take place or before a great deal of value is added to the product. In these cases the cost of inspection is less than the cost of adding more value to the product.

3. The critical inspection point is the finished product or service. In manufacturing, final products are frequently inspected prior to shipment or prior to placing the product in the inventory (Murray 1987).

The second step in process design is to decide on the type of measurement to be used at each inspection point. There are generally two options: measurements based either on variables or on attributes. Variable measurements utilize a continuous scale of such factors as length, height, or weight. Attribute measurements use a discrete scale by counting the number of defective items or the number of defects per unit. When the quality specifications are complex, it is necessary to use attribute measurements.

The third step in defining the process design is to decide on the amount of inspection to use. The choices are generally 100 percent inspection or a sample portion of the output. The guiding principle of this decision is to compare the cost of passing defects to the cost of inspection.

The final step in process design is deciding who should do the inspection. Usually a combination of inspections by the workers themselves and by outside inspectors is used. If a philosophy of zero defects or make it right the first time is used, the workers are given much of the responsibility for inspection and only a minimum amount of outside inspection is used.

In some cases, the customer is involved in inspecting the product. Service customers always take this role as they achieve the service. Some customers station inspectors at the vendor plants to examine and accept or reject shipments before they are sent to the customer (Treleven 1986).

Finally, all of the steps require a series of management judgements. The control principles themselves are elementary, requiring performance standards, measurements, and feedback of results to correct the process. However, the application of these principles in any given situation is complex. One of the aids which helps define the proper degree of control, however, is to utilize the control chart concept which is explained in detail in the following section.

Statistical quality control aims at testing quality by allowing certain latitude due to random variation only. There are two categories of statistical quality control, acceptance sampling and process control. Acceptance sampling aims at accepting or rejecting an entire lot, based on statistical evidence found in a sample. Testing the entire population (e.g., a lot from a day's production) may not be economical and may sometimes destructive (e.g., strength of material). Besides, research has shown that a 100 percent inspection may have to be repeated four times to be hundred percent effective, due to human error or fatigue which typically occurs in monotonous assembly operations.

On the other hand, process quality arises when a sampling sequence element, usually time, is involved.

The primary objective is not only to determine if the process is under control, but to anticipate problems and to take corrective action before costly defects occur. This is accomplished by establishing two control limits, within which the measured characteristic must lie with certain confidence.

Basically there are three types of control charts (Mann 1988):

1. Variables--when the characteristic of interest is not an attribute (proportion defective or number of defects), but a usually continuous scale measurement, like dimensions of a product, manhours, or costs. These charts are referred to as the X-chart for the sample mean and the R-chart for the sample range.

2. Proportion or fraction defective--when the attribute of interest is a rate like the fraction of defective items in a sample, the proportion of equipment idle time or worker absenteeism. These are known as P-charts.

3. Number of defects per unit--such as the number of blemishes of a painted surface or a cloth per unit area. They are called C-charts.

Factor 8: Quality Data

Doing it wrong the first time is industry's largest single quality expense. The estimated cost of bringing goods back in line with customer requirements can range as high as 40 percent of sales for many firms, with the industry average running close to 25 percent (Crosby 1979). In effect, firms are spending a quarter of their income patching their own mistakes. With so many firms carrying such a major non-productive expense on their back, it is not surprising that the United States industry has a hard time staying competitive with quality conscious nations such as Japan and Germany. However, in recent years, more and more United States firms are learning that they can cut operating costs significantly-and boost their profit margins at the same time-by tightening quality standards and cutting the cost of conformance sharply (Semich 1987).

Theoretical discussions of the relationship between quality and cost fall into two distinct categories (Garvin 1984). The first group argues that quality and direct cost are positively related. The implicit assumption here is that quality differences reflect variances in performance, features, and other product attributes that require more expensive materials, additional labor hours, or other commitment of tangible resources. This view of quality dominates much American thought on the subject.

A second view sees quality and cost as inversely related, because the costs of improving quality are thought to be less than the resulting savings in rework, scrap and warranty expense. According to this view, which is widely held among Japanese managers, quality is synonymous with the absence of defects, and the costs in question are quality costs.

Typically, quality costs can be broken into control costs and failure costs. Control costs are related to activities which remove defects from the production stream. This can be done in (1) by prevention and (2) by evaluation or appraisal. The prevention costs include activities such as quality planning, new-product reviews, training and engineering analysis. These activities occur prior to production and are aimed at preventing defects before they occur. In a perfect world, prevention costs would not exist. But with a good prevention program, most other costs of conformance to quality should disappear. The other category of control costs comprises appraisal or inspection aimed at eliminating defects after they occur but before the products reach the consumer. Appraisal costs include testing of incoming goods, supplier surveillance, inspection of product while in process, cost of products damaged by test process, purchase and maintenance cost of test equipment, product acceptance, and packaging inspection.

Appraisal costs rise as quality falls. In a perfect world--one where suppliers are responsible for pretesting and for total quality control of their own products--appraisal costs can approach zero. In fact, it is in reducing appraisal costs that many purchasing departments have made a name for themselves within their companies. Failure costs are incurred either during the production process (internal) or after the product is shipped (external). The internal failure costs include such items as scrap, rework, downgrading, and machine downtime. The external failure costs include warranty charges, returned goods, allowances and complaints.

The total cost of quality can thus be expressed as a sum of the following costs.

Total cost of quality = (prevention & appraisal costs)
+ (internal & external failure costs)

The total cost of quality can be minimized by observing the relationship between cost of quality and degree of conformance. When degree of conformance is very high (low defects), the cost of failures is low but the cost of controls is quite high. When the degree of conformance is low (high defects), the opposite situation exists. Thus, there is, between the two extremes, an optimal level of conformance where total quality costs are minimized. Good quality management also requires the proper balance between appraisal and prevention costs, so that total control costs are at minimum. Finally, the cost of quality can be a powerful tool for quality control when properly used. It focuses management's attention on waste due to excess failures and also provides a quantitative basis for monitoring progress in reducing quality costs to the desired level.

Noori (1990) points out the following issues that must be considered regarding the measurement of quality costs:

1. Quality must be defined in terms of costs so that the true cost of quality becomes apparent to management.

2. Investments aimed at improving quality must be properly evaluated.

3. Quality programs should not conflict with other company programs and objectives should be focused primarily on reducing costs.

4. Problem-solvers should not automatically look for the least expensive solution to solve quality problems.

Apart from availability of quality cost data, organizations should emphasize the concept of timely quality measurement and evaluate managers and employees based on quality performance.

Factor 9: Feedback and Employee Relations

Many employees do not understand how to do their jobs or what constitutes good performance. They feel powerless because management has control over them. They are afraid to point out problems because they might be blamed. Such fear creates appalling economic loss.

Elimination of fear must begin at the top of an organization. Employees must be treated with respect. They must be given the necessary knowledge and tools to do their jobs properly. They must understand the organization's goals and the part they play in the achievement of those goals. Management must focus on the positive and eliminate the negative. The organization's climate must encourage openness, reward positive action, and expose problems so that they may be understood and corrected. Supervisors must focus on continual improvement rather than production quotas. They must understand statistical process control so that they do not hold workers responsible for the results of natural process variation which is beyond the workers' power to control. They must constantly work to improve the team concept in their organizations (Heldt 1988).

Deming (1986) suggests lifetime employment as a way of driving out fear. This alone does not have the desired effect. Without establishing the philosophy and methods necessary for continual improvement, lifetime employment can result in a perpetuation of mediocrity.

American companies generally do not treat their employees as the most valuable asset in the corporation.

Too frequently they are treated as mere factors of production. Managers in such companies see no purpose in communicating company goals to employees or in listening to ideas from employees. Employees working under such conditions feel a loss of pride. They cannot identify with the company's mission--they do not even know what the company's mission is. This, of course, does not stop managers from blaming employees when the goals are not reached (Finney and Stone 1987).

Another factor which erodes pride of workmanship is providing workers with inadequately designed products, faulty equipment, materials, or methods. This leads workers to believe that producing a good quality product is beyond their control (Dowst 1988).

Both organizations and the individual employees benefit from a rebirth of pride of workmanship. Removing the barriers enables a company to achieve a more competitive position in the marketplace, and enables workers to develop positive feelings about themselves and their work. Management must take a long-term approach to removing these barriers. Employees should be involved in the improvement process. The quality of the materials, tools, equipment, and methods must match the quality goals for the finished product.

Summary

The review of literature has revealed that there exist several distinct schools of thought, often treated as mutually exclusive quality philosophies. For example, Deming 1986) has been an evangelist for simple, straightforward, quantitative methods that prevent quality slippage rather than fixing it after it has slipped. Deming's cornerstone message is that competitive quality cannot be attained with traditional quality control inspection methods, no matter how tight or thorough the procedure. Juran (1974) focuses on the design of products that are both high quality and manufacturable to consistently high-quality standards. He, too, waxes verbose on the issue of participation beyond the manufacturing or engineering level. Crosby's (1979) method offers the comfort and guidance of a prescriptive set of sequence of activities rather than global norms. Finally, Feigenbaum's (1986) approach promotes that no quality improvement is obtained from a system that is not dedicated to quality in every aspect of its operation.

The literature findings show that despite superficial differences, there are several relatively independent critical factors contributing to reject rates and employee job involvement. They are: top management, quality policies, role of the quality department, training, product design, vendor quality management, process management, quality data, feedback and employee relations. A brief explanation of these critical factors is elucidated in this

CHAPTER III

METHODOLOGY

In this chapter the methodology utilized in this research is presented. First, the research hypotheses and the research design are explained. Next, the subjects and the instrument used in the measurement of quality assurance practices are defined. Finally, the data analysis procedures used are addressed.

Research Hypotheses

The review of relevant literature suggests the following specific null hypotheses:

Hypothesis 1.--There is no difference in the level of quality between multinational Indian manufacturing organizations and local Indian manufacturing organizations.

Hypothesis 2.--There is no difference in the level of quality between specific industry type and manufacturing industry as a whole.

Hypothesis 3.--There is no association between corporate management support for quality and the level of quality achieved.

Hypothesis 4.--There is no association between specific quality policies and the level of quality achieved.

Hypothesis 5.--There is no association between the role performed by the quality department and the level of quality achieved.

Hypothesis 6.--There is no association between the emphasis placed on training and the level of quality achieved.

Hypothesis 7.--There is no association between systematic product design and the level of quality achieved.

Hypothesis 8.--There is no association between the emphasis on vendor quality management and the level of quality achieved.

Hypothesis 9.--There is no association between comprehensiveness process management and the level of quality achieved.

Hypothesis 10.--There is no association between the availability and use of quality data and the level of quality.

Hypothesis 11.--There is no association between the extent of employee involvement in quality efforts and the level of quality.

Research Design

First, a literature review was performed to identify the critical factors needed for effective quality management. As part of the field study, a questionnaire and letter explaining the purpose of the study were personally given to general managers or quality managers of 75 organizations. Time was spent with these managers in order to gather more information about the organizations' quality assurance programs. The organizations were selected on the basis of total sales volume and number of employees.

After questionnaires were returned, they were coded on the basis of their responses with values between 5 (strongly agree) and 1 (strongly disagree). Several statistical techniques were performed on the data collected to test the various hypotheses. Finally, the data base was used to forecast quality.

Research Subjects

According to Nunnally (1967), when a measuring instrument is used for data collection, the subjects used should be those for whom the instrument is intended. The organizations' quality assurance managers or the general managers were the subjects used in this study because they are likely to be the most knowledgeable about quality management.

For the purpose of this study, only manufacturing organizations with more than 500 employees and a total sales volume of more than 251 million rupees, or $15 million, were considered since the quality management practices of such organizations were relatively more sophisticated, or at the very least more completely developed. The main source for the preparation of the sampling frame was Kothari's Economic and Industrial Guide of India (1988-1989). The organizations surveyed represent industries classified under the manufacturing division of the SIC Manual (1987), specifically sections 20 to 30. The manufacturing division includes establishments engaged in the mechanical or chemical transformation of materials or substances into new products. Specifically, sections 20 to 30 include the following components: food and kindered products, tobacco products, textile mills products, apparel, lumber and wood products, furniture and fixtures, paper and allied products, printing and allied products, chemicals and allied products, petroleum refining, rubber, plastics and miscellaneous products (SIC manual 1987). For reasons of practicality, managers were chosen from organizations in the five major cities of India: Ahmedabad, Bombay, Calcutta, Delhi, and Madras. A convenience sample of 75 organizations (25 multinational and 50 local) fitted the above classification (SIC 20 to 30) and were requested to participate in this study. A high participation rate was anticipated due to the personal-contact approach used.

Research Instrument

For the purpose of this study, the instrument developed by Saraph, Benson, Schroeder (1989) to evaluate quality management practices in manufacturing or service organizations was used (Appendix A). This instrument was used because (1) the measures are empirically based and shown to be valid and reliable, and (2) the instrument measures directly or indirectly all the critical factors identified in this study.

To enable managers to indicate the degree or extent of practice of each item by their organization, a five-point Likert-type scale was used. For each critical factor, the level of practice can be represented by the mean reported score for that factor.

The reliability and validity techniques used in developing the instrument and the results obtained are summarized:

1. In order to test the reliability of empirical measurements the internal consistency method was used (Appendix B). Internal consistency was estimated using the reliability coefficient Cronbach's alpha (α). The reliability coefficients (α) of the measures ranged from 0.79 to 0.91 (Table 3). Reliability coefficients of 0.70 or more are considered adequate (Cronbach 1951; Nunnally 1967).

2. Content validity was used to test the validity of the instrument. The content validity of the instrument was subjectively judged. The critical factors of quality management had content validity because: (1) an extensive review of the literature was conducted in selecting the

measurement items and the critical factors, and (2) all the items and factors were carefully evaluated by professionals in the academic and business fields.

It was concluded that the results concerning the measures developed were encouraging and that the instrument could be utilized to produce a profile of organization wide quality management.

Data Analysis Procedure

For the purpose of analyzing the data, the following statistical techniques were used:

1. Frequency distribution and percentage measures of selected data. A frequency distribution is any device, such as a graph or table, that displays the values that a variable can assume along with the frequency of occurrence of these values, either individually or as they are grouped into a set of mutually exclusive and exhaustive intervals (Kvanli, Guynes, and Pavur 1989).

2. Basic statistics such as mean, standard deviation, and variance are also computed. The means and standard deviation are calculated using Thurnstone's Case V analysis and Fisher's Least Square Difference (LSD). Case V is selected for analysis not because it is a sophisticated procedure, but because it presents the results in a clear and simple way which can be easily understood by managers.

Table 3:--Reliability of Factors Affecting Quality

Factors	Number of Items Per Factor	Alpha (α)
Top management	7	0.7989
Quality policies	6	0.8870
Role of the quality department	5	0.8763
Training	8	0.7978
Product design	6	0.8146
Vendor quality management	8	0.7988
Process design	11	0.9066
Quality data	8	0.8487
Feedback and employee relations	8	0.8500

The Case V analysis takes, as input, individual level of data, and develops a group level interval scale in which the stimuli are assigned a value ranging from 1 to 0 (Malhotra 1986; and Malhotra, Taschian, and Mahmoud 1987). In relative terms, the most important factor is assigned a value of 1.00. It should be noted, however, that a factor assigned a value of 0.00 should not be interpreted as having no importance. The correct interpretation is that this factor is relatively the least important.

On the other hand, the least square difference procedure provides a measuring stick for comparing the amount of separation necessary between any two sample means before a significant difference can be declared to exist between the corresponding population means (Imen and Conover 1983).

3. Analysis of variance (ANOVA) was used to identify the difference among the means of various groups in the model. This indicates whether there exists a statistical difference in the level of quality between multinational Indian organizations and local Indian organizations, and also whether there exists a statistical difference in the level of quality between a specific industry type and the manufacturing industry as a whole.

4. The remaining nine hypotheses formulated for this study were initially tested for statistical significance using the correlation coefficient. The Pearson coefficient of correlation is a measure of the strength of the linear relationship between two variables X (dependent variable--level of quality) and Y (independent variable--nine critical factors) (Mendenhall and Sincich 1989).

5. Finally, for the purpose of forecasting quality and selecting a model, multiple regression analysis was performed. Multiple regression analysis is a statistical technique that can be used to analyze the relationship

between a single dependent (criterion) variable and several independent (predictor) variables (Mendenhall and Sincich 1989).

Limitations of the Study

There were several limitations to this research. First, factors influencing quality assurance were numerous. A comprehensive analysis of all of the factors (variables) was beyond the scope of this study. Behavioral and cultural factors that may have a direct impact on an organization's commitment to quality assurance were not considered in this study. Consequently, any generalization drawn from the present study is limited to the dependent and independent variables employed.

Second, the sample size of the study was seventy-three Indian manufacturing organizations. Seventy percent of these organizations are chemical and pharmaceutical industries. Because of this, there may be an undue influence of the peculiarities of certain industries. This may have biased the overall results.

Third, this study has limited external validity. Though carefully selected, the sample frame is restricted to one developing country. Therefore, making generalization about quality assurance programs in other developing countries based on the results of this study may not be appropriate without further research.

Next, this study relied on one respondent to complete the instrument in each organization. There is always some risk associated in relying on just one individual's perspective.

Finally, this study has an exploratory orientation. Its objective was to see and describe what the existing quality assurance practices were. As a result, the relationships were not subjected to cross validation through another sample. The reason for this was that the original sample size was small; therefore, all data were used for the statistical analysis.

CHAPTER IV

RESULTS OF THE STATISTICAL ANALYSIS

The results of the statistical analysis are presented in this chapter. First, a brief explanation of the techniques (analysis of variance, correlation coefficient and regression analysis) used to test the hypotheses and forecast quality is given. Second, a summary of the characteristics of the sample is presented in the form of frequency distributions and mean scores for various variables. Next, responses to the research questions and the results pertaining to research hypotheses testing are reported. Finally, regression models are generated that can effectively forecast the level of quality.

Statistical Techniques

As previously mentioned, analysis of variance and correlation coefficient analysis were used in testing the hypotheses and measuring relationships between the variables. The regression analysis procedure was used to forecast quality.

The analysis of variance technique shows the part of the total variation of data that might be attributed to specific causes or sources of variation, and then compares it with that part of the variation of the data that can be attributed to chance (Daniel and Terrell 1983). In this method, a general null hypothesis of no difference among the means of various groups is tested. If the difference among the means of various groups is greater than the difference that can be attributed to chance, the null hypothesis is rejected. In such a case, the alternative hypothesis would be accepted, and it would be concluded that the differences among the means were associated with the sources of variation stated in the alternative hypothesis (Kvanli, Guynes, and Pavur 1989).

The Pearson product-moment correlation coefficient measures the strength of linear relationships between two variables. It "tells us whether or not it is reasonable to say that there exists a linear relationship (correlation) between $\underline{x}$ and $\underline{y}$." (Draper and Smith 1981) The value of the statistic $\underline{r}$ (Pearson product-moment coefficient of correlation) ranges from negative one to positive one. The stronger the relationship between two variables, the closer the correlation coefficient to one. If the relationship is weak, r will be close to zero. The direction of relationship is denoted by the sign of $\underline{r}$ (+ or -). A positive relationship is represented by +$\underline{r}$, and a -$\underline{r}$ is an indication of a negative association (Neter, Wasserman, and Kutner 1985). "The interpretation of a coefficient correlation coefficient as a measure of the linear relationship between two variables does not involve any cause and effect implications. A high value for the coefficient of correlation simply implies a high degree of 'co-relation'" (Kvanli, Guynes, and Pavur 1989).

In presenting a correlation coefficient, information needs to be provided concerning three aspects. First, the degree of relationship (r), second the direction of the relationship (+ or -), and, finally, the probability that the relationship that the relationship might be due to chance (P) (Cook 1979).

As noted earlier, multiple regression analysis is a general statistical technique that can be used to examine the relationship between a single dependent variable or a set of independent variables. The objective of multiple regression analysis is to use the several independent variables whose values are known to predict the single dependent value sought.

In order to select the best predictive model, several assumptions about the variables to be used and the relationship between these variables need to be made. For the purpose of this study, the following assumptions are made and tested for: (1) Since this study deals with sample data representing human behavior perception, a statistical relationship rather than a functional relationship is assumed. (2) It is assumed that at each level of the predictor variable, the values of the criterion variable all have the same variance (homoscedasticity). (3) The error is not always positive at one level of prediction and negative at another (Larsen and McCleary 1972).

There are many approaches that can be used to determine the best predictive model using regression analysis. The four most common are backward elimination, forward elimination, stepwise selection, and all-possible-subsets regression (Montgomery and Peck 1982).

Regardless of which approach is used, an important step in model building should be to eliminate the problems, if any, created by multicollinearity. Multicollinearity exists when highly correlated independent variables are present in a regression model. The two main problems that arise when serious multicollinearity is present in the regression analysis are: (1) high correlations among the independent variables resulting in an increase in the likelihood of rounding errors in the calculation of the β estimates, and standard errors, and (2) confusing and misleading regression results (Draper and Smith 1981). According to Mosteller and Tukey (1977), the following are indicators of multicollinearity: (1) significant correlations between pairs of independent variables in the model, (2) nonsignificant *t*-tests for the individual β

parameters when the $\underline{F}$-test for overall model adequacy is significant, (3) opposite signs (from what is expected) in the estimated parameters, and (4) a variation inflation factor (VIF) for a β parameter greater than 10.

Once multicollinearity has been detected, there are several alterative measures available for solving this problem (Mendenhall and Sincich 1989). The first is to drop one or more of the correlated independent variable from the final model. The second, if all variables are to be kept, is to avoid making inferences about the individual β parameters. The third is to use a designed experiment if the ultimate goal is to establish a cause-and-effect relationship. Next, is to code the independent variables, so that first-, second-, and higher-order terms for a particular X variable are not highly correlated. Examples of coding or transformation include adding two or more variables, or multiplying two or more variables, among others. The final measure is to reduce rounding errors and stabilize the regression coefficients by using ridge regression to estimate the parameters. The appropriate measure to take depends on the severity of the multicollinearity and the ultimate goal of the regression analysis (Rawlings 1988).

After the multicollinearity problem is resolved, a thorough examination of the errors in prediction (residuals) is performed to examine the appropriateness of the predictive model. The predictive model is examined in terms of (1) the linearity of the phenomenon measured, (2) the constant variance of the error terms, (3) the independence of the error terms, (4) the normality of the error term distribution, and (5) the addition of other variables (Mendenhall and Sincich 1989).

Characteristics of the Sample

Managers of seventy-three Indian manufacturing organizations, a response rate of 97 percent, served as respondents in this study. Table 4 provides summary information, in the form of frequency distributions, for the respondents who participated in the survey.

The majority of the respondents, 50.7 percent, were general managers. The remaining 49.3 percent were quality assurance managers or directors directly in charge of manufacturing. Over 93 percent of the respondents had 16 or more years of formal education and at least 10 years of work experience. About 29 percent of the respondents had a doctorate degree while 69 percent had a master's degree. These data indicate that the respondents had the qualifications and background necessary to effectively participate in the study.

Table 4:--Respondent Information

	n	Percent
Position or Title		
General Manager	37	50.7
Quality Assurance Manager	21	28.8
Directors (Manufacturing)	15	20.5
Total	73	100.0
Years of education		
> 21	31	42.5
16 - 20	37	50.7
< 16	5	6.9
Total	73	100.0
Highest degree		
Doctorate	21	28.8
Master's	50	68.5
Bachelors (diplomas)	2	2.7
Total	73	100.0
Years of experience		
> 21	29	39.7
16 to 20	28	38.4
11 to 15	15	20.2
< 11	2	2.7
Total	73	100.0

Table 5 provides summary information of the characteristics of the 73 organizations used as the sample for this study. Of these organizations, 83.6 percent were publicly owned organizations while the remaining were privately owned.

Table 5.--Organization Information

	n	Percent
Organization type		
Public	61	83.6
Private	12	16.4
Total	73	100.0
Class of organization		
Multinational	25	34.2
Local	48	65.8
Total	73	100.0
Industry type		
Chemical	27	37.0
Pharmaceutical	24	32.9
Other manufacturing	22	30.1
Total	73	100.0
Types of products manufactured		
Industrial	25	34.2
Consumer	19	26.0
Both	29	39.8
Total	73	100.0
Number of products manufactured		
2	7	9.6
3	18	24.7
4	18	24.7
5	2	2.7
6	28	38.4
Total	73	100.0

Table 5.--Continued

	n	Percent
Total sales volume (in million of rupees)		
251-750	15	20.6
751-1250	19	16.0
1251-1750	19	16.0
1751-2250	10	13.7
> 2251	10	13.7
Total	73	100.0
Number of employees		
500-999	29	39.7
1000-2499	19	26.1
2500-4999	9	12.3
> 5000	16	21.9
Total	73	100.0
Number of first-line supervisors		
< 25	2	2.7
26-50	8	11.0
51-75	11	15.1
76-100	22	30.1
101-125	18	24.7
> 125	12	16.4
Total	73	100.0
Quality assurance employees		
26-50	16	21.9
51-75	10	13.7
76-100	21	28.8
101-125	12	16.4
> 126	14	19.2
Total	73	100.0

Table 5.--Continued

	n	Percent
Location of head office		
Bombay	50	68.5
Delhi	9	12.3
Madras	5	6.9
Calcutta	9	12.3
Total	73	100.0
Location of plant		
Bombay (Thane)	41	56.2
Delhi	8	11.0
Madras	10	13.7
Calcutta	8	11.0
Ahmedabad	6	8.2
Total	73	100.0
Quality policy		
Formal written	70	96.0
Informal	3	4.0
Total	73	100.0
Quality department		
Organized/separate	70	96.0
No Separate	3	4.0
Total	73	100.0
Customer service department		
Organized/Separate	70	96.0
No Separate	3	4.0
Total	73	100.0

Table 5.--Continued

	n	Percent
Quality standards for incoming materials/parts		
Technical standards set	73	100.0
No standards set	0	0.0
Total	73	100.0
Labor characteristics		
Union	72	98.6
Non-union	1	1.4
Total	73	100.0

The majority of the organizations, 65.8percent, were local Indian organizations, and the remaining 34.2 percent were multinational corporations. Based on industry type, 37 percent represented the chemical industry, 32.9 percent represented the pharmaceutical industry, and the remaining 30.1 percent represented other manufacturing industries. There was a near-equal distribution between the three groups as far as industry type classification was concerned.

All of the organizations manufactured two or more varieties of consumer or industrial products. They maintained quality policies and technical quality standards for incoming raw materials and parts. Ninety-six percent of the organizations operated both quality and customer service departments.

Finally, 64.4 percent of the organizations employed 76 or more individuals in their quality assurance department. In addition, 86.3 percent of the organizations employed 51 or more first-line supervisors.

Responses to Research Questions

In this section, the results pertaining to the research questions proposed in this study are reported.

Manufacturing Objectives

The questionnaire used in this study identified four major manufacturing objectives: producing quality products, meeting production schedules, manufacturing low-cost products, and improving work productivity. Managers were asked to assign ranks to each category on the basis of their rating of its importance as a manufacturing objective (Table 5).

Though producing quality products and services is not the primary manufacturing objective, it does not lag far behind, as depicted in Table 6. In contrast, the objectives of low-cost production and improve work productivity were ranked lower. The respondents felt that these objectives had already been implemented successfully.

Quality Department

Ninety-six percent of the organizations studied operated independent quality departments (Table 5). The role of the quality departments included maintaining clearly defined quality policies, stressing product and process design, working closely with suppliers, coordinating with other departments, and providing necessary feedback.

In most organizations the quality assurance department was managed by the General Manager of Quality Assurance. In others, it was under the control of the Industrial Engineering or Manufacturing Manager. Some organizations also had separate inspection departments in each plant directly under the Technical Manager of that plant.

Ninety-six percent of the organizations studied maintained formal quality policies (Table 5). These policies were in written form and were approved and endorsed by top management. Also, a consistent operational definition of quality existed throughout the organization.

Causes of Quality Problems

The questionnaire identified seven causes of quality problems: workmanship or workforce, materials or purchased parts, maintenance or adjustments of process or equipment, poor design of process or equipment, poor product design, inadequate systems of controls, and management errors (Garvin 1984).

Table 6:--Relative Importance of Manufacturing Objectives (n = 73)

Relative Importance	Rank of Objectives	Mean Score [a,b]
1.0000	1. Meeting Production Schedule	1.671(μ_1)
0.9240	2. Producing Quality Products	1.822(μ_2)
0.4343	3. Low Cost Production	2.795(μ_3)
0.0000	4. Improve Work Productivity	3.658(μ_4)

[a] For each objective, respondents rated its importance on a scale of "1" to "4", where "1" represented "the most important objective."

[b] Using Fisher's Least Square Difference Procedure indicated the correct relative ordering of the mean scores at $\alpha = 0.05$ to be: $\mu_1 = \mu_2 > \mu_3 > \mu_4$.

Managers were asked to assign ranks to each category on the basis of their rating of its importance as a cause of their organizations' quality problems. Table 7 indicates the rank order of the causes of quality problems faced by Indian manufacturing organizations. Out of the seven causes stated in the questionnaire, materials or parts purchased and maintenance or adjustment of process or equipment were the most important causes of quality problems while an inadequate system of control and management errors were ranked the least important.

In order to solve the quality problems, Indian manufacturing organizations are adopting the concept of sharing or joint responsibility. Purchasing, design, marketing and production departments are working together to achieve quality goals. Many organizations are also trying to involve vendors as part of this integral system.

Cost Reporting System

Almost 83 percent of the organizations surveyed reported the employment of a quality cost reporting system. When asked if the cost reporting sysem was consistent, 78 percent of the organizations responded positively (Table 8).

Eighty percent of the organizations measured the cost of conformance to quality standards or guidelines, while 56.2 percent measured costs incurred due to nonconformance.

Table 7:--Relative Importance of Causes of Quality Problems
($\underline{n}$ = 73)

Relative Importance	Rank of Causes	Mean Score[a,b]
1.0000	1. Materials/Parts Purchased	2.836(μ_1)
0.9916	2. Maintenance/Adjustment of Process/Equipment	2.863(μ_2)
0.9061	3. Workshop/Workforce Problems	3.137(μ_3)
0.8121	4. Poor Product Design	3.438(μ_4)
0.6024	5. Poor Design of Process /Equipment	4.110(μ_5)
0.1622	6. Inadequate Systems of Control	5.521(μ_6)
0.0000	7. Management Errors	6.041(μ_7)

[a] For each cause, respondents rate its importance on a scale of "1" to "7", where "1" represented "the most important cause".

[b] Using Fisher's Least Square Difference Procedure indicated the correct relative ordering of the mean scores at $\alpha = 0.05$ to be: $\mu_1 = \mu_2 > \mu_3 = \mu_4 > \mu_5 > \mu_6 > \mu_7$

The questionnaire also identified the following four components of the total cost of maintaining quality: prevention costs, appraisal costs, internal failure costs, and external failure costs. Managers were asked to assign ranks to each category on the basis of their rating of its importance as a component of the total cost.

Table 8: -- Manufacturing Related Costs
(n=73)

Cost	Percent of Responses Yes	No
Quality cost reporting system	82.2	17.8
Consistent cost reporting system	78.1	21.9
Cost of conformance computed	79.5	20.5
Cost of nonconformance computed	56.2	43.8

Table 9 indicates the rank order of the components comprising the total cost of maintaining quality. Prevention cost and appraisal cost were ranked higher than internal and external failure costs. The prevention costs incurred were mainly in areas of quality planning, new-product development, training and engineering analysis. The appraisal or inspection cost incurred included testing of incoming goods, supplier surveillance, inspection of product in process, cost of products damaged by test process, product acceptance, and packaging inspection.

Table 9:--Relative Importance of Major Components of Total Costs ($\underline{n}$ = 73)

Relative Importance	Rank of Major Components	Mean Score[a,b]
1.0000	1. Prevention Costs	2.342 (μ_1)
0.7793	2. Appraisal Costs	2.466 (μ_2)
0.6085	3. Internal Failure Costs	2.562 (μ_3)
0.0000	4. External Failure Costs	2.904 (μ_4)

[a] For each component, respondents rated its importance on a scale of "1" to "4", where "1" represented "the most important component".

[b] Using Fisher's Least Square Difference Procedure indicated the correct relative ordering of the mean scores at $\alpha = 0.05$ to be: $\mu_1 > \mu_2 = \mu_3 > \mu_4$.

Training Programs

Ninety-six percent of the organizations surveyed maintained on-the-job training programs to educate and communicate a focus on quality to managers and employees (Table 5). Off-the-job training programs were also very common. The major objectives of these training programs included explaining the overall organization operations, product quality specifications and improving the basic skills of the employees. Special training programs were also conducted to enhance the knowledge of managers and workers in the functioning of special processes, advanced statistical methods, and sophisticated equipment.

Testing the Research Hypotheses

In this section, the results pertaining to the research hypotheses addressed in this study are reported. APPENDIX B provides summary information, in the form of mean scores, for the dependent and independent variables used in this study.

Null Hypothesis 1

There is no difference in the level of quality between multinational Indian manufacturing organizations and local Indian manufacturing organizations.

Analysis of variance was used to test whether there existed a difference in the level of quality between multinational Indian organizations and local Indian organizations. Since there were two dependent variables, in the first analysis of variance procedure the level of quality was measured by assembly line rejects (dependent variable 1) while in the second analysis the level of quality was measured by after delivery rejects (dependent variable 2). The results of the analysis of variance procedures are reported in Table 10 (also, see Appendix D). In both instances, there existed no significant difference in the level of quality between local Indian organizations and multinational organizations at $\alpha = 0.05$. The result is not surprising because this survey covered the top manufacturing organizations in India, and these organizations, whether local or multinational, must maintain a necessary level of quality in order to stay competitive in the global marketplace. In addition, the Indian Statistical Institute stipulates rigorous standards that must be satisfied by all manufacturing organizations. Since no relationship existed, all 73 observations were treated as one data set.

Null Hypothesis 2

There is no difference in the level of quality between specific industry type and manufacturing industry as a whole.

Two separate analyses of variance were conducted to determine whether or not a significant difference existed. The first analysis of variance determined the relationship between specific industry type (chemical industry, pharmaceutical industry, and other manufacturing industries) and assembly line rejects, while the second determined the relationship between industry type and after-delivery rejects. In other words, two separate runs were used for the two dependent variables.

Table 10.--Multinational versus Local Organizations

Source	DF	Sum of Squares	Mean Squares	*F*	Prob. *F*
ANOVA - Assembly Line Rejects by V113 (Multinational)					
Between Groups	1	1.3904	1.3904	2.5496	0.1148*
Within Groups	71	38.7192	0.5453		
Total	72	40.1096			

* $p > 0.10$

Source	DF	Sum of Squares	Mean Squares	*F*	Prob. *F*
ANOVA - After Delivery Rejects by V113 (Multinational)					
Between Groups	1	0.7717	0.7717	3.1013	0.0825*
Within Groups	71	17.6667	0.2488		
Total	72	18.4384			

* $p < 0.10$

The results of these analysis of variance procedures are reported in Table 11 (also, see Appendix D). Based on the p-values, it can be concluded that there existed no significant relationship between specific industry type and the level of quality. This result is not surprising because all the manufacturing organizations studied were somewhat similar in size. This is supported by Kothari's Economic and Industrial Guide to India (1988-1989), which classifies pharmaceutical as a part of the chemical industry;

Table 11.--Quality Level and Industry Type

Source	DF	Sum of Squares	Mean Squares	F	Prob. F
ANOVA - Assembly Line Rejects by V114 (Industry Type)					
Between Groups	2	0.4126	0.2063	0.3638	0.6963*
Within Groups	70	39.6970	0.5671		
Total	72	40.1096			

* Not significant

Source	DF	Sum of Squares	Mean Squares	F	Prob. F
ANOVA - After Delivery Rejects by V114 (Industry Type)					
Between Groups	2	0.0141	0.0071	0.0268	0.9736*
Within Groups	70	18.4242	0.2632		
Total	72	18.4384			

* Not significant

therefore, companies have to maintain very similar quality standards. The Indian chemical industries generally have good quality control procedures. These companies have quality policies which are documented and sent to all factories from the head offices, nationally or abroad. In some companies the policy document is prepared for each and every department separately with clear objectives.

Null Hypotheses 3 through 11

There is no association between the level of quality and (1) top management, (2) quality policies, (3) role of the quality department, (4) training, (5) product design, (6) vendor quality management, (7) process design, (8) quality data, or (9) feedback and employee relations.

Tables 12 and 13 show the results of correlation analyses for these variables. From Table 11 it can be seen that there is a highly significant negative correlation between assembly line rejects and training, vendor quality management, and process design. There also exists a significant negative correlation between assembly line rejects and quality policies, role of the quality department, and quality data. In other words, as the quantity of assembly line rejects decreased, the level of quality increased. Since, training, vendor quality management, and process design were independent variables that brought about the decrease in assembly line rejects, there exists a positive relationship between these independent variables and the level of quality. The positive relationship is brought about by the reduction in the level of rejects.

Table 12.--Pearson's Coefficient of Correlation for Assembly Line Rejects

Critical Factor	r	p-value
Top management	0.1062	0.186
Quality policies	-0.4344	0.001*
Role of the quality department	-0.3842	0.001*
Training	-0.7233	0.000*
Product design	0.1246	0.147
Vendor quality management	-0.6753	0.000*
Process design (SQC)	-0.7212	0.000*
Quality data	-0.2821	0.008*
Feedback and employee relations	0.2820	0.242

* $p < 0.01$

Similar correlations existed when studying the relationship between after delivery reject rates and the independent variables--quality policies, role of the quality department, quality training, vendor quality management, process design, and quality cost data. On the other hand, no significant relationship was found between after delivery rejects and the independent variables--top management, product design, and feedback and employee relations. Interpretation of these results is found in Chapter V.

Table 13.--Pearson's Coefficient of Correlation for After Delivery Rejects

Critical Factors	r	p-value
Top management	0.0851	0.237
Quality policies	-0.3050	0.004*
Role of the quality department	-0.2586	0.014**
Training	-0.6045	0.000*
Product design	0.0094	0.468
Vendor quality management	-0.5768	0.000*
Process design (SQC)	-0.6317	0.000*
Quality data	-0.2948	0.006*
Feedback and employee relations	0.0942	0.214

* $p < 0.01$

** $p < 0.05$

Forecasting Quality

Forecasting quality by means of econometric models can help policy makers to identify the most important variables and the relationships between variables, thus enabling policy makers to plan more appropriately. This section is exploratory with respect to forecasting quality, because the exact nature of such relationship has not yet been established. Therefore, the existence of a relationship is the prime area of focus.

Multiple regression analysis was used to generate models that could be used by organizations to predict the level of quality. These models represents a formal attempt to account for the effects of critical factors on the perceived level of quality forecasting. Since the industries are classified into three groups (chemical, pharmaceutical, and others), separate regression models were developed for each group and for the two surrogates measuring the level of quality (assembly line rejects and after delivery rejects). A total of six forecasting models were generated.

The Model

The overall research models are hypothesized to be:

$$Y_A = \beta_0 - \beta_1 X_1 - \beta_2 X_2 - \beta_3 X_3 - \beta_4 X_4 - \beta_5 X_5 - \beta_6 X_6 - \beta_7 X_7 - \beta_8 X_8 - \beta_9 X_9 + \epsilon_i$$

$$Y_B = \beta_0 - \beta_1 X_1 - \beta_2 X_2 - \beta_3 X_3 - \beta_4 X_4 - \beta_5 X_5 - \beta_6 X_6 - \beta_7 X_7 - \beta_8 X_8 - \beta_9 X_9 + \epsilon_i$$

where:

Y_A = Assembly line rejects
Y_B = After delivery rejects
β_0 = Intercept
$\beta_1, \ldots \beta_9$ = Slope
X_1 = Top management
X_2 = Quality policies
X_3 = Role of the quality department
X_4 = Quality training
X_5 = Product design

X_6 = Vendor quality management
X_7 = Process design
X_8 = Quality Data
X_9 = Feedback and employee relations
ϵ_i = Random observation for observation i

Analysis and Results

As the regression models were developed, it became obvious that some modifications in the model and elimination and transformation of some variables were necessary. In addition, some relatively common minor problems with multiple regression were anticipated, tested for, and solved. This section describes the model modification, presents the results, and describes the procedure used for residual analysis and reduction of the regression models.

Model Modification

The research was designed to test the relationship between the level of quality and independent operating variables (critical quality factors) using a regression model methodology. Multicollinearity, an initial concern, developed as a problem for the regression models. A high correlation existed between the following independent variables: X_2 and X_3, $r = 0.8351$; X_4 and X_6, $r = 0.9018$; X_4 and X_7, $r = 0.8988$; X_6 and X_7, $r = 0.9123$. Since the goal of this study was to develop models for estimation and prediction purposes, rather than dropping the independent variables, a transformation to the values of the independent variables was performed to provide a better approximation to E(y). Coding or transformation of variables was performed in such a way that the first-, second-, and higher-order terms for a particular independent variable were not highly correlated.

Regression Results

Once the initial investigation of multicollinearity was completed, the analysis continued in three stages. The first step was the basic multiple linear regression using each dependent variable with all independent variables. The second stage involved a complete residual analysis. The final stage involved the stepwise selection of variables to investigate the stability of the relationships and to produce final reduced models.

Initial regression results. Because no prior order of inclusion existed in the model, forced-entry multiple regression was used on the independent variables using first the assembly-line rejects and then the after-delivery rejects as the dependent variable for each of the three industrial classifications. A summary of the key results is presented in Tables 14 through 19. The utility of the models were checked using the analysis of variance F-test and the multiple coefficient of determination criteria. No implication of importance should be given to the order of inclusion for the independent variables in the table.

Residual analysis. After the initial regression models were computed, an analysis of the residuals was conducted to determine if the prior assumptions of linearity and 61 homoscedascity were valid (see Appendix D).

Table 14.--Initial Forecasting Model for Chemical Industry Using Assembly Line Rejects

Variable	Beta	*t*	Significance
Top management	-0.097613	-0.778	0.4465
Quality department	0.041485	0.146	0.8859
Quality policies	-0.256250	-0.908	0.3761
Quality training	-0.615368	-1.728	0.1010
Product design	-0.073774	-0.636	0.5325
Process design	-0.109368	-0.319	0.7536
Vendor management	-0.066934	-0.214	0.8330
Quality data	-0.043364	-0.239	0.8141
Feedback	-0.267550	1.844	0.0816

Multiple *R* = 0.90361
R square = 0.81652
F = 8.90034
Significance of *F* = 0.00010

The primary method used to test the distribution normality of residuals was the chi-square goodness of fit. The chi-square tests, conducted on the residuals of each regression, indicated the acceptance of normality for the dependent variables.

Table 15.--Initial Forecasting Model for Chemical Industry Using After Delivery Rejects

Variable	Beta	*t*	Significance
Top management	-0.177751	-0.981	0.3396
Quality department	0.159581	0.380	0.7028
Quality policies	-0.318165	-0.780	0.4455
Quality training	-0.221188	-0.430	0.6723
Product design	-0.037759	-0.225	0.8241
Process design	-0.458255	-0.925	0.3674
Vendor management	0.223926	0.495	0.6263
Quality data	-0.355833	-1.355	0.1921
Feedback	0.412952	1.971	0.0644

Multiple *R* = 0.78552
R square = 0.61705
F = 3.22257
Significance of *F* = 0.01660

However, further examination of the histogram of the residuals indicated a couple of outliers. None of the outliers independently affected the regression adversely (according to the calculations of individual Cook's D values). According to Neter, Wasserman, and Kutner (1985), the offending outlier should be eliminated from the model only if it can be determined that the measurement was incorrect; otherwise it should remain. Because this was an early and exploratory research, it was decided to keep the outliers in the analysis. However, future researchers using this model should be aware of this problem.

Table 16.--Initial Forecasting Model for Pharmaceutical Industry Using Assembly Line Rejects

Variable	Beta	*t*	Significance
Top management	-0.205293	-1.033	0.3181
Quality department	-0.089307	-0.340	0.7387
Quality policies	-0.310210	-1.087	0.2941
Quality training	-0.197370	-0.701	0.4937
Product design	-0.304317	-1.730	0.1042
Process design	-0.693377	-2.099	0.0532
Vendor management	-0.022071	-0.066	0.9482
Quality data	0.294921	1.424	0.1749
Feedback	-0.040921	-0.300	0.7679

Multiple *R* = 0.88980
R square = 0.79174
F = 6.33630
Significance of *F* = 0.00090

Stability and reduced model analysis. After full model regressions were completed, stepwise selection of variables was conducted for all six regression models. The reason for using the stepwise selection procedure was because the other procedures do not take into account the effect that the addition or deletion of a variable can have on the contributions of other variables to the model (Bendel and Afifi 1977).

Table 17.--Initial Forecasting Model for Pharmaceutical Industry Using After Delivery Rejects

Variable	Beta	*t*	Significance
Top management	-0.344744	-1.260	0.2269
Quality department	-0.039024	-0.108	0.9155
Quality policies	-0.271947	-0.693	0.4992
Quality training	0.286211	0.739	0.4712
Product design	-0.361161	-1.492	0.1565
Process design	-0.934206	-2.055	0.0578
Vendor management	-0.157570	-0.342	0.7368
Quality data	0.258635	0.907	0.3785
Feedback	0.111751	0.596	0.5599

Multiple *R* = 0.77815
R square = 0.60552
F = 2.55831
Significance of *F* = 0.05290

Table 18.--Initial Forecasting Model for Miscellaneous Manufacturing Industry Using Assembly Line Rejects

Variable	Beta	*t*	Significance
Top management	-0.576425	-2.161	0.0560
Quality department	-0.003539	-0.012	0.9905
Quality policies	-0.288975	-1.228	0.2474
Quality training	-0.223332	-0.405	0.6939
Product design	-0.347288	-1.951	0.0797
Process design	-0.532658	-1.517	0.1603
Vendor management	-0.063402	-0.116	0.9098
Quality data	0.250606	0.766	0.4614
Feedback	0.366597	1.545	0.1534

Multiple *R* = 0.89815
R square = 0.80668
F = 4.63634
Significance of *F* = 0.01250

A variable added early to the model in forward selection can become unimportant after other variables are added, or variables previously dropped in backward elimination can become important after other variables are dropped from the model. On the other hand, the stepwise selection method is a forward selection process that rechecks at each step the importance of all previously included variables. If the partial sum of squares for any previously included variables does not meet a minimum criterion for remaining in the model, the selection procedure changes to backward elimination and variables are dropped one at a time until all remaining variables meet the minimum criterion, then, forward selection resumes (Hocking 1976).

Table 19.--Initial Forecasting Model for Miscellaneous Manufacturing Industry Using After Delivery Rejects

Variable	Beta	t	Significance
Top management	-0.576425	-2.161	0.0560
Quality department	-0.003539	-0.012	0.9905
Quality policies	-0.288975	-1.228	0.2474
Quality training	-0.223332	-0.405	0.6939
Product design	-0.347288	-1.951	0.0797
Process design	-0.532658	-1.517	0.1603
Vendor management	-0.063402	-0.116	0.9098
Quality data	0.250606	0.766	0.4614
Feedback	0.366597	1.545	0.1534

Multiple R = 0.89815
R square = 0.80668
F = 4.63634
Significance of F = 0.01250

This stepwise procedure eliminated variables with nonsignificant beta values and those that were marginally significant ($p < 0.10$) from the regression for all six models. The purpose of these regressions was to determine the stability of the relationships without the influence of the nonsignificant and marginally significant variables. The final reduced models results are shown in Tables 20, illustrating that the significance of the relationships determined in the full model was maintained for all variables involved. These regressions not only present the final reduced relationship that can be used for predictive purposes but also help to confirm the lack of any major multicollinearity problems in the model.

Stepwise Procedure: An Illustration

In this section, an illustration of how the stepwise procedure for variable selection was used to develop models that can predict the level of quality is demonstrated. In the case illustrated, an effort is made to develop a model that can predict the assembly line rejects for the pharmaceutical industry. Similar methodology was used for developing models for other industries in the study.

Before the stepwise procedure was used, a check for multicollinearity was performed. Since multicollinearity existed between variables X_1, X_2, X_4, X_6, and X_8, it was decided to transform the values of these variables rather than keep them as they were, in order to provide a better approximation to $\underline{E}(y)$. For the purpose of transformation, these variables were added and multiplied together.

Table 20.--Models of Factors Contributing to the Level of Quality for Each Industry Type (Alpha = 0.10)

Independent variable	Intercept	Beta	*t* prob.	*F* prob.	*R* square
Chemical Industry (Assembly line rejects)					
Training	7.6644	-1.5231	0.0000	0.0000	0.7656
Chemical Industry (After delivery rejects)					
Process design	5.1631	-0.9011	0.0000	0.0000	0.4975
Pharmaceutical Industry (Assembly line rejects)					
(Training x Process design)	8.1373	-0.3313	0.0000	0.0000	0.7490
(Product design x Feedback)		-0.0847	0.0890		
Pharmaceutical Industry (After delivery rejects)					
Process design	7.3141	-1.1791	0.0000	0.0001	0.5840
(Top management x Product design)		-0.0783	0.0270		
Miscellaneous Industries (Assembly line rejects)					
Top management	21.2507	-3.4517	0.0000	0.0001	0.7087
(Training x Process design)		-0.2382	0.0010		
(Training x Training)		-0.1557	0.0050		

Table 20.--Continued

Independent variable	Intercept	Beta	t prob.	F prob.	R square
Miscellaneous Industries (After delivery rejects)					
Product design	13.8923	-1.5061	0.0104	0.0003	0.6842
Top management		-0.9136	0.0830		
(Training x Training)		-0.1557	0.0055		

For example, instead of considering variable X_1 and X_2 independently, they were transformed by considering them together. Table 21 through 23 contains a summary of the steps used in developing the best additive, multiplicative, and second-order models.

Table 21.--Best Additive Model for Pharmaceutical Industry Using After Delivery Rejects

Variable	Beta	t	Significance
Training + Process design	-1.023528	-7.631	0.000
(Constant)	9.730426	9.537	0.000

Multiple R = 0.84667
R square = 0.71686
F = 58.23106
Significance of F = 0.00000

Table 22.--Best Multiplicative Model for Pharmaceutical Industry Using After Delivery Rejects

Variable	Beta	*t*	Significance
Training x Process Design	-0.297267	7.569	0.0000
(Constant)	6.293745	10.846	0.0000

Multiple *R*	=	0.84472
R square	=	0.71355
F	=	57.29391
Significance of *F*	=	0.00000

However, the best model could be a combination of these three models. To obtain the best overall model the stepwise procedure was used.

Table 23.--Best Squared Model for Pharmaceutical Industry Using After Delivery Rejects

Variable	Beta	*t*	Significance
Process Design x Process Design	-0.145748	-2.659	0.0143
Training x Training	-0.150518	-2.258	0.0342
(Constant)	6.291616	10.187	0.0000

Multiple *R*	=	0.84326
R square	=	0.71109
F	=	27.07395
Significance of *F*	=	0.00000

There are several stages in the stepwise regression process. The first stage is to set the termination rule. Here, the termination rule expressed in terms of significance level to enter and stay was set at $\alpha = 0.10$. In the next step, the best single variable generated by the stepwise procedure was training times process design, which provided $(100)R^2 = 71.35\%$ and $F = 57.29$.

The corresponding significance level of 0.00 is far beyond the significance level set. The third step of the stepwise selection computes the partial sums of squares for each of the remaining variables in a model that contains training times process design plus that particular variable. The partial sum of squares for product design times feedback was the largest and gave $t = -1.777$ and probability > $t = 0.0894$, which satisfied the criterion for entry. Thus product design times feedback was added to the model. After the third step when training times process design and product design times feedback are both in the model, the stepwise procedure rechecks the contribution of each variable to determine if each should stay in the model. Since both the variables have a large F ratio with probability > F much smaller than $\alpha = 0.10$, both these variables stayed in the model.

The stepwise procedure then checks to see if any other variable meets the criterion to enter the model. Since the probability > t for all the remaining variables were larger than $\alpha = 0.10$, the selection process terminated with the two variable subset (training times process design and product design times feedback).

Thus, the stepwise procedure started with one variable (training times process design) and added, in the next step, the second variable (product design times feedback) and stopped because the remaining variables at this stage had an $\alpha > 0.10$. If the significance level to enter was greater than 0.10, stepwise regression would have followed the same path and added more variables that met the criteria.

Factors Contributing to the Level of Quality

The regression analysis indicated that several strong relationships existed as hypothesized; those stable relationships were maintained when the model was reduced. All six estimated regression models had fairly high values of *R*-squared. It should be noted that the *R*-squared values for the models predicting assembly line rejects were substantially higher than for the models predicting after delivery rejects. This implies that these critical factors do a better job in forecasting assembly line rejects than after delivery rejects.

The overall *F*-tests and the individual coefficient t-tests were also significant at $\alpha = 0.10$ for all six estimated regression models. Thus, the models have predictive and explanatory value.

Forecasting assembly line rejects can be determined as a function of quality training ($p < 0.0000$) for the chemical industry; quality training times process design ($p < 0.000$) and product design times feedback ($p < 0.0894$) for the pharmaceutical industry; and top management involvement ($p < 0.0003$), and training ($p < 0.0013$) for the miscellaneous manufacturing industries.

On the other hand, forecasting after delivery rejects can be determined as a function of process design ($p < 0.0000$) for the chemical industry; process design ($p < 0.0000$) and top management times product design ($p < 0.0272$) for the pharmaceutical industry; and product design ($p < 0.0003$), training ($p < 0.0830$) and training times training ($p < 0.0055$) for the miscellaneous manufacturing industries.

Although this investigation of the critical factors contributing to success in forecasting the level of quality is exploratory, and much more research needs to be done, the results suggest that certain critical factors are related to success in forecasting the level of quality.

CHAPTER V

INTERPRETATIONS OF THE RESULTS, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

In this chapter, the main goal is to summarize and analyze the findings of the research. Initially, a summary of how the study was conducted is presented. Then the results reported in Chapter IV are interpreted and discussed. The final section contains recommendations for future research.

Summary of the Study

As stated in the first chapter, the purposes of this study are three-fold. First, critical factors necessary to achieve effective quality management were identified. The second purpose was to obtain Indian managers' perceptions of the quality assurance programs in their organizations. Finally, an attempt was made to develop models that could be used to forecast the level of quality achieved.

For the purpose of identifying critical factors, the quality philosophies of Deming (1982, 1982, 1986), Juran (1974, 1978, 1981, 1986, 1988, 1989), Crosby (1979, 1989), Ishikawa (1976, 1988), Feigenbaum (1961, 1983, 1985, 1986,

1989) and Garvin (1983, 1984) were assimilated. Through a judgmental process of grouping similar requirements it was found that all the requirements for effective quality management could be classified into the following nine major critical factors: (1) top management, (2) quality policies, (3) role of the quality department, (4) training, (5) product design, (6) vendor quality management, (7) process design (statistical quality control), (8) quality data, and (9) feedback and employee relations.

To measure managers' perceptions about quality management practices in Indian organizations, an instrument developed by Saraph, Benson, Schroeder (1989), was utilized. Only manufacturing organizations employing more than 500 employees, with a total sales volume of over 251 million rupees, were included in the sample since it was thought that the quality management practices of these organizations were likely to be more sophisticated. Seventy-three organizations participated in this study. The characteristics of the sample were presented in Chapter IV. Correlation analysis and analyses of variance were used to analyze the collected data. The results of the statistical analysis were also reported in Chapter IV. Based on the results of statistical analysis, the following findings pertaining to the nine factors:

1. Contrary to what was reported in the literature, there exists no relationship between top management support for quality and the level of quality achieved.

2. A positive relationship exists between specific quality policies and the level of quality achieved.

3. A positive relationship exists between the role played by the quality department and the level of quality achieved.

4. A positive relationship exists between the emphasis placed on training and the level of quality achieved.

5. No relationship exists between systematic product design and the level of quality achieved.

6. A positive relationship exists between the emphasis on vendor quality management and the level of quality achieved.

7. A positive relationship exists between comprehensiveness process management and the level of quality achieved.

8. A positive relationship exists between the availability and use of quality cost data and the level of quality achieved.

9. No relationship exists between the extent of employee involvement in quality efforts and the level of quality achieved.

Conclusions

The most important conclusion drawn from this study relates to the practical application of some of the findings. Managers, regardless of their position, expect an organization, to a great extent, to implement the nine critical quality factors to a great extent. Thus, the factors seem to be somewhat universally acceptable and consistent with the findings of Garvin (1984, 1985), Saraph, Benson, and Schroeder (1989), and other quality philosphers. To remain competitive in quality, managers must carefully review how these nine critical areas of quality assurance fare in organizations and must constantly improve practices in areas where deficiency is perceived. Interpretation of the findings and conclusions for the individual critical factors are discussed first. Next, overall conclusions that emerged from this study are analyzed. Finally, the implications of the findings of this study for managers in dealing with quality are discussed.

Factor 1: Top Management

According to quality experts, successful quality performance requires persons in top management who are dedicated to that goal (Crosby 1979, 1989). In other words, those in top management must provide the initiative for successful quality assurance practices and must support the quality program in the organization if such a program is to be successful. However, this study did not offer statistical support for such a conclusion. This could be attributed to several possible reasons. First, the primary manufacturing objective of Indian organizations is meeting the production schedule. Second, those in top management do not assume direct responsibility for quality performance. Instead, the acceptance for responsibility is designated to quality department personnel. Third, there exists a lack of comprehensiveness of the goal-setting process for quality within the organizations. Fourth, little importance is attached to quality by those in top management in relation to cost and schedule objectives. Next, quality issues are not reviewed on a regular basis at top management meetings. Finally, the degree of participation by major department heads in the quality improvement process is minimal.

Factor 2: Quality Policies

This study offers significant statistical support for the hypothesis that specific quality policies are the practical embodiments of an organization's attitudes toward quality and, therefore, help in improving the level of quality. This evidence supports the quality philosophies of Juran (1974) and Garvin (1983, 1984). This can be attributed to several reasons.

First, in Indian organizations, well-documented quality policies with clear objectives existed for each and every department in the organization. The quality policies were mainly oriented toward customer satisfaction. Second, the organizations' policies concerning quality were determined by the achievment of the following goals: government regulations, customer expectation, market share, company reputation, and profitability. In order to satisfy customer needs, the organizations tried to meet the specifications provided by the customers and the standards stipulated by the Indian Statistical Institute. Finally, these quality policies were reviewed periodically. According to the respondents, all levels of personnel were aware of their responsibilities toward quality.

Factor 3: Role of the Quality Department

Research has shown that for an organization to be efficient, the quality department should be visible, autonomous and have direct access to top management (Ishikawa 1976; Leonard and Sasser 1982; Mondon 1982). This study offers significant statistical evidence to support these results. In Indian organizations, the quality department played a positive role in improving the level of quality. The major responsibilities of the quality department included formulating and improving major quality improvement programs and working closely with other departments. Procedures for quality control covered the entire business, from development to marketing, purchasing, manufacturing, and distribution. The quality departments also prepared various types of reports on summaries of defects and failures at the various stages of processing and final inspection.

Factor 4: Training

This study extended significant statistical support for the hypothesis that emphasis on quality training improves the level of quality. This evidence is consistent with the findings of Crosby (1979), Deming (1986), Juran (1974), and Mondon (1982), that, if an organization is to grow and prosper, a formal and quality training program must exist. Effective and efficient training programs to educate and communicate its focus on quality to its managers and employees were present in each of the organizations studied. In addition to on-the-job training, off-the-job training programs, specifically in form of classroom exercises, were active. Training in special processes, advanced statistical methods, and sophisticated measuring equipment also existed. Even though, some managers complained that the training programs were merely academic exercises and were not understood by the illiterate workers, most of the respondents to the survey indicated that the training programs played a significant role in improving the quality of the organizations' products and services.

Factor 5: Product Design

This study provided no significant statistical support for the hypothesis that systematic product design improves the level of quality. This contradicts earlier results reported by Adam, Hershauer, and Rich (1981), Garvin (1983), Juran (1974), and Mondon (1982), that product design practices provide the ideal starting point for a study of quality performance. In Indian organizations, the development of products and the establishment of product and process design are the activities of the research and development department. However, many organizations surveyed did not operate their own independent research and development department. This was gathered when interviewing the managers of these organizations. Research and development activities were present only in some organizations at corporate level, while in most they were at lower levels.

Some respondents claimed that research and development activities accounted for a very high contribution toward company achievement. However, in most organizations where the research and development activities was at the plant itself, complaints were that insufficient interaction existed between the research and development department and the quality assurance and manufacturing departments. Other complaints included that the research and development activities were not based on any well-documented company policy, and were not communicated for practical applications.

Factor 6: Vendor Quality Management

Most Indian organizations have realized that working with vendors to improve their quality systems, as well as improving their own systems, are keys to success. This study provided significant statistical support to indicate that organizations that worked closely with their vendors had less problems with materials or parts purchased and had a higher level of quality, and vice versa. This evidence supports the findings of Adam, Hershauer, and Rich (1981), Deming (1982), and Juran (1974). In India, as compared to Japan, there is a desire to have alternate vendors (in relation to a single source) for as many materials as possible in order to assure constancy of supply and to provide bargaining leverage. Many respondents indicated that price, given a certain minimal level of quality, was yet the foremost criteria for selecting vendors. However, respondents also indicated that a standard system of providing feedback to suppliers concerning the quality of their raw materials existed, that technical assistance was also provided to vendors, and that plant personnel often visited vendors to help in problem definition and resolution.

Factor 7: Process Design (Statistical Quality Control)

Statistical quality control provides means for analyzing the process, continually improving the process, and controlling product quality through control of the process (Deming 1982). This study offered statistical support for the hypothesis that a comprehensive process design improves the level of quality, thus supporting the earlier findings of Crosby (1979), Deming (1982), Garvin (1983), Juran (1974), and Mondon (1982).

Quality control activities, which have been in operation in India since the 1960s (Chellaney 1990), are mainly based on the application of statistical quality control techniques. Most organizations studied maintained an effective system for monitoring incoming raw materials, checking in-process production, and reviewing finished products. Statistical quality control techniques were extensively used by these organizations (1) to decide whether to accept or reject lots of products purchased or made within the company, (2) to check the reasonableness of quality standards, and (3) to spotlight and correct process discrepancies. The Indian Statistical Institute also helps these organizations by providing services for the installation of statistical process control systems and also providing training for all personnel involved.

Factor 8: Quality Data

Availability and the use of quality data, especially quality cost data, is an essential ingredient of a strong quality program (Crosby 1979; Juran 1974; Mondon 1982). This study provides significant statistical support to the idea that the availability and use of quality cost data improves the level of quality. This could be attributed to several possible reasons. First, most of the organizations surveyed reported having an efficient quality cost reporting system that maintained data on vendors, defect or failures, error rates, scrap, warranty reports, cost of prevention, cost of appraisal, and customers' complaints. Second, these data were available for all divisions and were updated on a regular basis. Third, the quality data were not only available to managers and supervisors but also were displayed in the form of control charts at employee work stations for full-time and hourly employees to examine. Finally, quality data were used by organizations as tools to manage quality and to make necessary quality improvements.

Factor 9: Feedback and Employee Involvement

This study offers no statistical support for the hypothesis that proper feedback and employee involvement in quality efforts improves the level of quality. This, contradicts the earlier findings of Adam, Hershauer, and Rich (1981), Crosby (1979), Ishikawa (1976), and Mondon

(1982). This can be attributed to several reasons. First, among the organizations which had introduced employee involvement programs such as quality circles for tackling quality-related problems, some indicated that their circles had become non-functional. While reasons for failure were not clearly expressed by anyone, it was felt that the two main reasons were because (1) the role of quality was not properly understood by employees participating in this program, and (2) management did not appreciate the suggestions and recommendations made by the quality circles because of its other implications. Second, in most organizations what was most lacking was the appreciation for quality performance at all levels. In most organizations, employee promotions were not based solely on quality performance. Finally, even though individuals in some organizations were honored with rewards for superior performance in their tasks relating to quality, this was not adequate motivation to produce quality work, particularly because this was often done on a random basis and did not form a part of the documented quality policy.

In order to stay competitive, organizations must find ways and means for quality improvement and cost reductions through employee involvement. A new culture should be indoctrinated to employees across all functional levels.

The management should also keep track of individuals who play a superior role in solving quality problems.

The overall conclusion that emerged from this study was that, contrary to what was hypothesized in the model, it is not necessary for all the factors to be present to insure the success of the total quality program of the organization. In other words, even if a few of the factors were not present, it was possible to obtain the required level of quality. For example, in the organizations studied effective quality levels were obtained even in the absence of top management support, proper product design, and continual feedback about quality processes.

Forecasting Quality

In this study, the regression models were tested in order to explore relationships between the nine critical factors and the level of quality. The results of the forecasting process were expected to provide insights into those critical factors (operating independent variables) thought to be most important to achieving increased levels of quality. In order to achieve effective quality management, emphasis must be placed on these variables by policy-makers when evaluating their quality assurance programs.

Though, no model was found that adequately incorporated all the variables when forecasting the assembly-line rejects and after-delivery rejects for the three industrial classifications, the analysis did provide significant results. Based on the analysis, it is clear that for predicting assembly-line rejects managers can rely on the following factors: training ($p < 0.0000$) for the chemical industry; training times process design ($p < 0.000$) and product design times feedback ($p < 0.0894$) for the pharmaceutical industry; top management ($p < 0.0003$), and training ($p < 0.0013$) for the other manufacturing industries.

On the other hand, the success of forecasting after delivery rejects is dependent on process design ($p < 0.0000$) for the chemical industry; process design ($p < 0.0000$) and top management times product design ($p < 0.0272$) for the pharmaceutical industry; and product design ($p < 0.0003$), training ($p < 0.0830$) and training times training ($p < 0.0055$) for the other manufacturing industries. As such, these models can be used as indicators of an effective quality assurance implementation and as diagnostic and research tools for understanding the relationships between the critical factors and the level of quality. However, future researchers using these models should be aware of the two problems encountered during the study: (1) the problem of multicollinearity existed in the first-order regression models, and (2) several outliers were present. It should be noted that these variables may change over time. Additionally, because of the limited number of observations used in this study, the list of independent variables used is not exhaustive. More accurate models can be developed by identifying several behavioral and cultural variables. However, in spite of not using such independent variables, the accuracy of the forecasting models developed in this study was strenghtened by combining several variables. As was illustrated in the description of the forecasting model, a combination of factors certainly improves the forecasting accuracy.

Managerial Implications

The model and the research methods used in this study have several important uses for managers. First, this method can be very useful to an organization attempting to identify those characteristics often mentioned in the quality literature that may provide an opportunity to increase the level of quality in a specific environment. The model developed in Chapter II illustrates one approach to implementing quality assurance programs. The approach described in this research begins by identifying and analyzing the significant operating variables. Second, managers can use these significant operating variables to obtain a better understanding of the existing quality management practices and to assign responsibilities within the organization for achieving organization-wide improvements in quality. Finally, after plans for improvements have been made and implemented, the methodology reported in this study can again be used by managers to reanalyze the organization's position and to evaluate the cost-effectiveness of further improvements. The analysis of the new organization position may point to variables where further actions could bring about quality improvements.

This method and the regression models provide a methodology to gain improved insight into quality assurance by providing a representation of the important variables affecting quality in an organization and by providing a base for conducting future research on quality. Ideally, a cross-national study investigating several countries at the same time, using the same research instrument, would be a good starting point.

Recommendations for Future Research

In an exploratory study such as this, recommendations for future research should address the issues generated in this study. First of all, a replication of this study should prove helpful in reexamining the validity of its findings. Further empirical studies using larger sample sizes and greater geographical diversity may be helpful in validating specific parts of the model proposed in this study.

Another area of future research should be to expand on this study, and include more variables so that the applicability of the findings could be improved. This study did not include behavioral and cultural factors in the formulation of the propositions. Future researchers should use the same general format of this study, and include some of the variable mentioned.

Third, a different instrument with an adequate number of measures should be used to measure the variables under investigation. The validity of the findings can be strongly substantiated if the use of other instruments produce similar results.

Next, based on the results of the study and the data collected, cross-cultural comparisons of Indian quality assurance practices with quality assurance practices incorporated by manufacturing organizations in other countries can be useful for both organizations and countries wanting to compete effectively in the global market. Studies of such a nature would help in identifying successful organizational factors or successful quality practices that lead to superior quality performance.

Finally, developing a more precise operational measure, rather than using interval scales, for each of the factors would improve the results of the study.

APPENDIX A

RESEARCH INSTRUMENT

SURVEY

QUALITY ASSURANCE PRACTICES INCORPORATED BY MANUFACTURING ORGANIZATIONS IN SELECTED COUNTRIES

CASE: INDIA

THIS IS A CONFIDENTIAL SURVEY OF YOUR KNOWLEDGE AND PERCEPTIONS CONCERNING QUALITY ASSURANCE PROGRAMS IN YOUR ORGANIZATION. PLEASE ANSWER ALL QUESTIONS. YOU ARE PART OF A SELECT GROUP OF INDIVIDUALS OR PROFESSIONALS ASKED TO PARTICIPATE IN THE SURVEY. HENCE YOUR INPUTS ARE VITAL TO THE SUCCESS OF THE SURVEY. ALL RESPONSES WILL BE HELD IN STRICT CONFIDENCE.

SECTION I
FRAMEWORK OF QUALITY ASSURANCE

Please provide the following information about your organization and its products:

I. Organization's Characteristics

1. Does your organization have a formal, written statement of quality policy? __Yes __No
   If yes, what is it? (please attach a copy if possible) ____________________
   ____

2. Is there an organized quality department in your plant? __Yes __No
   If yes, to whom does the director/manager of the quality control (assurance) department report? __________
   ____

3. Is there a customer service department? __Yes __No

4. Are quality (technical) standards set for incoming materials/parts? __Yes __No
   If yes, what are they? ____________________
   ____

II. Manufacturing Characteristics

1. If you were to rank the manufacturing objectives emphasized by the top management of your organization, how would you rank them?

   (Assign scores of 1 to 4 where 1 stands for the most important objective and 4 for the least important objective)

   a. low-cost production ___
   b. meeting the production schedule ___
   c. producing high-quality (defect free) products ___
   d. improving work productivity ___

2. If you were to rank the "causes" of your quality problems, how would you rank them?

   (Assign scores of 1 to 7 where 1 stands for the most serious problem and 7 for the least serious problem)

   a. workmanship/workforce problems ___
   b. materials/parts we purchase ___
   c. maintenance/adjustment of process or equipment ___
   d. poor design of process or equipment ___
   e. inadequate systems or controls ___
   f. management errors (including providing insufficient instructions to the workforce) ___
   g. poor product design ___

3. What is the assembly line reject rate (the % of total defects per unit produced)?

   a. less than 1% b. 1-5% c. 6-10% d. 11-15%
   e. 16-20% f. greater than 20%.

4. What is the after delivery reject rate (the % of defective items returned by customer and/or that requires field service during the warranty period)?

   a. less than 1% b. 1-5% c. 6-10% d. 11-15%
   e. 16-20% f. greater than 20%

III. Product Characteristics

1. What percentage of the product's materials are purchased from outside vendors?

   a. less than 10% b. 10-25% c. 26-50% d. 51-75%
   e. greater than 76%

2. What percentage of purchased parts and materials are single sourced?

   a. less than 10% b. 10-25% c. 26-50% d. 51-75%
   e. greater than 76%

3. What percentage of incoming parts and materials are rejected as being below standard?

   a. less than 5% b. 5-10% c. 11-15% d. 16-20%
   e. greater than 20%

4. If the output does not meet the quality standards, what corrective action (on the output/process) does the quality control department implement? ____________________

IV. Labor Characteristics

1. Are your employees represented by a union? __Yes __No
2. How many shifts does your plant normally run?
   a. 1 [ ] b. 2 [ ] c. 3 [ ] d. 4 [ ]
3. What percentage of your direct labor is paid by hourly wages? ____________
4. Do you have "on the job" training? __Yes __No
   If no, what other kind of training programs are implemented? ____________

V. Manufacturing Related Costs

1. Does your firm employ a quality cost reporting system? __Yes __No
   If yes, is the cost reporting system employed by the organization consistent? __Yes __No
2. Do you measure cost of conformance to quality standards or guidelines? __Yes __No
3. Do you know what costs are incurred due to non-conformance? __Yes __No
4. If were asked to rank the components of the total cost of maintaining quality, how would you rank them?
   (Assign scores of 1 to 4 where 1 stands for the highest component of the total cost and 4 for the lowest component of total cost)
   a. Prevention __
   b. Appraisal __
   c. Internal Failure __
   d. External Failure __

SECTION II
QUALITY ASSURANCE CONCEPTS

Please CIRCLE the choice that best reflects your opinion:

	Extent or Degree of Current Practice Is				
	Very Low	Low	Medium	High	Very High
Factor 1: Top Management					
1. Extent to which the top executive (responsible for division profit and loss) assumes responsibility for quality performance	1	2	3	4	5
2. Acceptance for responsibility for quality by major department heads within the division	1	2	3	4	5
3. Degree to which divisional top management (top divisional executive and major department heads) is evaluated for quality performance	1	2	3	4	5
4. Extent to which the division top management supports long-term quality improvement process	1	2	3	4	5
5. Degree of participation by major department heads in the quality improvement proces	1	2	3	4	5
6. Extent to which divisional top management has objectives for quality performance	1	2	3	4	5
7. Specificity of quality goals within the division	1	2	3	4	5

	Extent or Degree of Current Practice Is				
	Very Low	Low	Medium	High	Very High
Factor 2: Quality Policies					
1. Comprehensiveness of the goal-setting process for quality within the division	1	2	3	4	5
2. Extent to which quality goals and policy are understood within the division	1	2	3	4	5
3. Importance attached to quality by the divisional top management in relation to cost and schedule objectives	1	2	3	4	5
4. Amount of review of quality issues in divisional top management meetings	1	2	3	4	5
5. Degree to which the divisional top management considers quality improvement as a way to increase profits	1	2	3	4	5
6. Degree of comprehensiveness of the quality plan within the division	1	2	3	4	5
Factor 3: Role of the quality department					
1. Visibility of the quality department	1	2	3	4	5
2. Quality department's access to divisional top management	1	2	3	4	5
3. Autonomy of the quality department	1	2	3	4	5
4. Amount of coordination between the quality department and other departments	1	2	3	4	5
5. Effectiveness of the quality department in improving quality	1	2	3	4	5
Factor 4: Training					
1. Specific work-skills training (technical and vocational) given to hourly employees throughout the division	1	2	3	4	5
2. Quality-related training given to hourly employees throughout the division	1	2	3	4	5
3. Quality-related training given to managers and supervisors throughout the division	1	2	3	4	5
4. Training in the "total quality concept" (i.e., philosophy of company-wide responsibility for quality) throughout the division	1	2	3	4	5
5. Training in the basic statistical techniques (such as histograms and control charts) in the division as a whole.	1	2	3	4	5
6. Training in advanced statistical techniques (such as design of experiments and regression analysis) in the division as a whole	1	2	3	4	5
7. Commitment of the divisional top management to employee training	1	2	3	4	5
8. Availability of resources for employee training in the division	1	2	3	4	5

Factor 5: Product design	Very Low	Low	Medium	High	Very High
1. Thoroughness of new product design reviews before the product is produced and marketed	1	2	3	4	5
2. Coordination among affected departments in the product development process	1	2	3	4	5
3. Quality of new products emphasized in relation to cost or schedule objectives	1	2	3	4	5
4. Clarity of product specifications and procedures	1	2	3	4	5
5. Extent to which implementation/producibility is considered in the product design process	1	2	3	4	5
6. Quality emphasis by sales, customer service, marketing, and PR personnel	1	2	3	4	5

Extent or Degree of Current Practice Is

Factor 6: Vendor quality management					
1. Extent to which vendors suppliers are selected based on quality rather than price or schedule	1	2	3	4	5
2. Thoroughness of the supplier rating system	1	2	3	4	5
3. Reliance on reasonably few dependable suppliers	1	2	3	4	5
4. Amount of education of supplier by division	1	2	3	4	5
5. Technical assistance provided to the suppliers	1	2	3	4	5
6. Involvement of the supplier in the product development process	1	2	3	4	5
7. Extent to which longer term relationships are offered to suppliers	1	2	3	4	5
8. Clarity of specifications provided to suppliers	1	2	3	4	5

Factor 7: Process design (Statistical quality control)					
1. Use of acceptance sampling to accept/reject lots or batches of work	1	2	3	4	5
2. Amount of preventive equipment maintenance	1	2	3	4	5
3. Extent to which inspection, review, or checking of work is automated	1	2	3	4	5
4. Amount of incoming inspection, review, or checking	1	2	3	4	5
5. Amount of in-process inspection, review, or checking	1	2	3	4	5
6. Amount of final inspection, review, or checking	1	2	3	4	5
7. Importance of inspection, review, or checking of work	1	2	3	4	5
8. Stability of production schedule/work distribution	1	2	3	4	5
9. Degree of automation of the process	1	2	3	4	5
10. Extent to which process design is "fool-proof" and minimizes the chances of employee errors	1	2	3	4	5
11. Clarity of work or process instructions given to employees.	1	2	3	4	5

	Extent or Degree of Current Practice Is				
	Very Low	Low	Medium	High	Very High
Factor 8: Quality data					
1. Availability of cost of quality data in the division	1	2	3	4	5
2. Availability of quality data (error rates, defect rates, scrap, defects, etc.)	1	2	3	4	5
3. Timeliness of quality data	1	2	3	4	5
4. Extent to which quality data are used as tools to manage quality	1	2	3	4	5
5. Extent to which quality data are available to hourly employees	1	2	3	4	5
6. Extent to which quality data are available to managers and supervisors	1	2	3	4	5
7. Extent to which quality data are used to evaluate supervisor and managerial performance	1	2	3	4	5
8. Extent to which quality data, control charts, etc. are displayed at employee work stations	1	2	3	4	5
Factor 9: Feedback and employee relations					
1. Extent to which quality circle or employee involvement type programs are implemented in the division	1	2	3	4	5
2. Effectiveness of quality circle or employee involvement programs in the division	1	2	3	4	5
3. Extent to which employees are held responsible for error-free output	1	2	3	4	5
4. Amount of feedback provided to employees on their quality performance	1	2	3	4	5
5. Degree of participation in quality decisions by hourly/nonsupervisory employees	1	2	3	4	5
6. Extent to which quality awareness building among employees is ongoing	1	2	3	4	5
7. Extent to which employees are recognized for superior quality performance	1	2	3	4	5
8. Effectiveness of supervisors in solving problems/issues	1	2	3	4	5

SECTION III

DESCRIPTION OF RESPONDENT AND ORGANIZATION

For classification purposes only, please answer the following questions. Responses to these questions will be held in strict confidence.

I. Personal Data of Respondent:

1) Name of Respondent: ____________ 2) Position or Title: ____________
3) Age: ____________ 4) Country of Origin: ____________
5) Sex ____________ 6) Years of Education: ____________
7) Highest Degree Earned ____________ 8) Years of Experience ____________

9) How would you classify your major functional responsibilities? (Please check the appropriate box)

a.	Accounting	[ ]	e.	Marketing	[ ]
b.	Engineering	[ ]	f.	Quality Control	[ ]
c.	Financial	[ ]	g.	Personnel	[ ]
d.	Manufacturing	[ ]	h.	Production Control	[ ]
i.	Inventory Control	[ ]	j.	Other ____________(Please specify)	

II. General Background of Organization:

1) Name of Organization: ____________

2) Type of Organization (Please check the appropriate box)

a. Public [ ] b. Private [ ]

3) Location of Head Office ____________ 4) Location of Plant(s) ____________

5) Product(s) Manufactured (Please check the appropriate box)

a. Industrial [ ]
b. Consumer [ ]
c. Both [ ]

6) What was your plant's total sales volume (In rupees)?

a.	Under 250 million	[ ]	d.	1251 - 1750 million	[ ]
b.	251 - 750 million	[ ]	e.	1751 - 2250 million	[ ]
c.	751 -1250 million	[ ]	f.	Over 2251 million	[ ]

7) How many employees does your plant have?

a.	Under 100	[ ]	d.	1000 to 2499	[ ]
b.	100 to 499	[ ]	e.	2500 to 4999	[ ]
c.	500 to 999	[ ]	f.	5000 or more	[ ]

8) How many first-line supervisors (in manufacturing) does your plant have?

a.	Under 25	[ ]	d.	76 to 100	[ ]
b.	26 to 50	[ ]	e.	101 to 125	[ ]
c.	51 to 75	[ ]	f.	126 or more	[ ]

9) How many quality control (assurance) employees (both supervisors and nonsupervisors) does your plant have?

a.	Under 25	[ ]	d.	76 to 100	[ ]
b.	26 to 50	[ ]	e.	101 to 125	[ ]
c.	51 to 75	[ ]	f.	126 or more	[ ]

10) How many different products are produced by your plant? (please do not count minor variations in styling or finishing)

a.	1	[ ]	d.	4	[ ]
b.	2	[ ]	e.	5	[ ]
c.	3	[ ]	f.	6 or more	[ ]

11) Is your organization a multinational? _____ Yes _____ No

(If Yes): To which country does the parent company belong to? ____________

12) Do you have any additional comments or suggestions which may be helpful to us?

____
____
____
____

<<<<<THANK YOU FOR YOUR COOPERATION>>>>>>

APPENDIX B

RESPONSES TO DEPENDENT AND INDEPENDENT VARIABLES

Table 24.--Responses to Dependent Variables

Percentage of Rejects	Multinational Organizations		Local Organizations	
	n	Percent	n	Percent
Assembly Line Rejects				
< 1	7	28.0	14	29.17
1 to 5	9	36.0	17	35.41
6 to 10	3	12.0	7	14.59
11 to 15	6	24.0	10	20.83
Total	25	100.0	48	100.00
After Delivery Rejects				
< 1	10	40.0	22	45.83
1 to 5	8	32.0	16	33.33
6 to 10	6	24.0	10	20.84
11 to 15	1	4.0	0	0.00
	25	100.0	48	100.00

Table 25.--Mean Score Responses for the Quality Assurance Critical Factors ($\underline{n}$ = 73)

Critical Factor	Mean Score
Factor 1: Top Management	
1. Extent to which the top executive assume responsibility for quality performance	3.8
2. Acceptance of responsibility for quality by major department heads	3.7
3. Degree to which divisional top management is evaluated for quality performance	3.5
4. Extent to which the top management supports long-term quality improvement process	4.0
5. Degree of participation by major department heads in the quality improvement process	3.8
6. Extent to which divisional top management has objectives for quality performance	3.8
7. Specificity of quality goals within the division	4.0
Factor 2: Quality Policies	
1. Comprehensiveness of the goal-setting process for quality within the division	4.0
2. Extent to which quality goals and policy are understood within the division	4.3
3. Importance attached to quality by the divisional top management in relation to cost and schedule objectives	3.9
4. Amount of review of quality issues in divisional top management meetings	3.8
5. Degree to which divisional top management considers quality improvement	3.9
6. Degree of comprehensiveness of the quality plan within the division	4.3
Factor 3: Role of the Quality Department	
1. Visibility of the quality department	4.5
2. Access to top management	4.3
3. Autonomy of the quality department	4.5
4. Coordination with other departments	4.4
5. Effectiveness in improving quality	4.3

Table 25.--Continued

Critical Factor	Mean Score
Factor 4: Training	
1. Specific work-skills training to hourly employees throughout the division	4.0
2. Quality-related training to hourly employees throughout the division	4.1
3. Quality-related training given to managers and supervisors	4.5
4. Training in the "total quality concept"	4.3
5. Basic statistical techniques training	4.7
6. Advanced statistical technique training	4.5
7. Commitment of top management to training	4.3
8. Availability of resources for training	4.7
Factor 5: Product Design	
1. Thoroughness of new product design	4.0
2. Coordination among affected departments	3.8
3. Quality emphasized in relationship to cost and schedule	3.5
4. Clarity of product specification	3.8
5. Extent to which implementation considered	3.8
6. Quality emphasis by sales, customer service, marketing, and PR personnel	3.7
Factor 6: Vendor Quality Management	
1. Selection based on quality	3.8
2. Thoroughness of the supplier rating system	4.2
3. Reliance on few dependable suppliers	4.0
4. Amount of education of supplier	4.2
5. Technical assistance provided to supplier	4.6
6. Involvement in the product development	4.4
7. Long term relationships offered	4.3
8. Clarity of specifications provided	4.8

Table 25.--Continued

Critical Factor	Mean Score
Factor 7: Process Design	
1. Use of acceptance sampling	4.5
2. Amount of preventive equipment maintenance	4.6
3. Automation of inspection, review of work	4.5
4. Inspection or review of incoming materials	4.7
5. Inspection or review of work-in-process	4.4
6. Inspection or review of final products	4.6
7. Importance of inspection or review of work	4.3
8. Stability of production	4.5
9. Degree of automation of process	4.4
10. Extent to which process design is "full-proof"	4.3
11. Clarity of work or process instructions	4.3
Factor 8: Quality Data	
1. Availability of cost of quality data	4.6
2. Availability of quality data	4.5
3. Timeliness of quality data	4.6
4. Use of quality data to manage quality	4.4
5. Quality data available to managers	4.7
6. Quality data used for evaluation	4.2
7. Quality data displayed at work stations	4.5
Factor 9: Feedback and Employee Relations	
1. Employee involvement programs implementation	3.7
2. Effectiveness of involvement programs	3.5
3. Employees responsible for error free outputs	3.3
4. Feedback provided to employees	3.8
5. Participation in quality decisions	3.8
6. Quality awareness among employees	3.6
7. Recognition of employees for quality performance	3.5
8. Effectiveness of supervisors in solving problems	3.5

APPENDIX C

RELIABILITY ANALYSIS

Table 26.--Reliablility Analysis for the Critical Factors ($\underline{n}$ = 73)

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Alpha If Item Deleted
Factor 1: Top Management				
TM1	24.5616	7.9718	0.6944	0.7402
TM2	24.6164	7.8231	0.6377	0.7509
TM3	24.5753	8.6088	0.5294	0.7729
TM4	24.7123	8.4855	0.6107	0.7582
TM5	24.6986	8.1301	0.7004	0.7408
TM6	24.5890	8.3288	0.6350	0.7531
TM7	24.6027	11.5205	-0.1025	0.8585
No of Cases = 73.0				
Alpha = 0.7989				
Factor 2: Quality Policies				
QP1	32.6986	37.4079	0.6700	0.8731
QP2	32.8356	36.6115	0.6867	0.8717
QP3	32.8493	38.4353	0.5767	0.8788
QP4	32.7671	38.2367	0.6004	0.8774
QP5	32.6027	36.6039	0.7084	0.8704
QP6	32.6164	38.6842	0.5418	0.8809
No of Cases = 73.0				
Alpha = 0.8870				
Factor 3: Role of the Quality Department				
QD1	32.7123	36.2078	0.7081	0.8702
QD2	32.8219	36.7595	0.6203	0.8763
QD3	32.6986	39.0468	0.5292	0.8815
QD4	32.7397	38.3341	0.6127	0.8768
QD5	32.7945	39.5544	0.4108	0.8895
No of Cases = 73.0				
Alpha = 0.8763				

Table 26.--Continued

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Alpha If Item Deleted
		Factor 4: Training		
TR1	24.5753	17.6366	0.2732	0.8071
TR2	23.8493	21.6575	-0.3204	0.8656
TR3	24.1781	13.9817	0.7369	0.7353
TR4	24.2055	14.9711	0.5645	0.7659
TR5	24.2055	14.7766	0.6992	0.7453
TR6	24.3288	14.7766	0.6555	0.7522
TR7	24.1781	15.0015	0.6379	0.7536
TR8	24.2740	13.7572	0.7962	0.7252
No of Cases = 73.0				
Alpha = 0.7978				
		Factor 5: Product Design		
PD1	21.1507	7.8242	0.5187	0.7975
PD2	21.1781	7.3151	0.5926	0.7820
PD3	21.1370	7.4532	0.5534	0.7904
PD4	21.1096	7.3212	0.6021	0.7800
PD5	21.0411	7.1788	0.5956	0.7812
PD6	21.0959	6.8657	0.6023	0.7805
No of Cases = 73.0				
Alpha = 0.8146				
		Factor 6: Vendor Quality Management		
VQM1	23.8082	18.6849	-0.0549	0.8408
VQM2	24.4247	15.1366	0.5313	0.7738
VQM3	24.6849	15.2744	0.4344	0.7875
VQM4	24.5479	13.9178	0.6031	0.7607
VQM5	24.1918	14.7683	0.5408	0.7716
VQM6	24.1918	13.2405	0.7001	0.7432
VQM7	24.2877	13.7633	0.6065	0.7599
VQM8	24.3288	13.7515	0.6705	0.7500
No of Cases = 73.0				
Alpha = 0.7988				

Table 26.--Continued

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Alpha If Item Deleted
		Factor 7: Process Design (SQC)		
SQC1	35.3151	37.3299	0.7699	0.8914
SQC2	35.3288	36.3349	0.7525	0.8922
SQC3	35.3014	37.8246	0.6903	0.8959
SQC4	35.3836	36.7953	0.7240	0.8940
SQC5	35.3425	38.7839	0.7015	0.8957
SQC6	34.6986	46.3246	-0.0244	0.9220
SQC7	35.3699	38.2085	0.7473	0.8932
SQC8	35.2466	37.1050	0.7086	0.8949
SQC9	35.3973	39.4094	0.6724	0.8974
SQC10	35.4247	37.5255	0.7726	0.8914
SQC11	35.4110	40.3565	0.4972	0.9061
No of Items = 11				
Alpha = 0.9066				
		Factor 8: Quality Data		
DATA1	24.0959	18.0879	0.7951	0.8016
DATA2	24.2877	19.3189	0.7153	0.8141
DATA3	24.1781	18.8706	0.6707	0.8197
DATA4	24.2192	20.8957	0.5851	0.8311
DATA5	24.2192	19.0624	0.6858	0.8175
DATA6	24.3425	20.3672	0.6121	0.8276
DATA7	24.1507	20.4909	0.6362	0.8252
DATA8	23.6301	26.2641	-0.0874	0.8873
No of Items = 8				
Alpha = 0.8487				

Table 26.--Continued

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Alpha If Item Deleted
	Factor 9: Feedback and Employee Relations			
FB1	24.5753	17.6366	0.2732	0.8071
FB2	23.8493	21.6575	-0.3204	0.8656
FB3	24.1781	13.9817	0.7369	0.7353
FB4	24.2055	14.9711	0.5645	0.7569
FB5	23.8082	18.6849	-0.0549	0.8408
FB6	24.4247	15.1366	0.5313	0.7738
FB7	24.6849	15.2744	0.4344	0.7875
FB8	24.5479	13.9178	0.6031	0.7607

No of Items = 8
Alpha = 0.8500

APPENDIX D

ANALYSES OF VARIANCE RESULTS

- O N E W A Y - - - - - - - - - - - - - - - - -

Variable V16 ASSEMBLY LINE REJECTS
By Variable V113 MULTINATIONAL

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	1.3904	1.3904	2.5496	.1148
WITHIN GROUPS	71	38.7192	.5453		
TOTAL	72	40.1096			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
Grp 1	25	1.4800	.5099	.1020	1.0000	2.0000	1.2695 TO 1.6905
Grp 2	48	1.7708	.8313	.1200	1.0000	5.0000	1.5295 TO 2.0122
TOTAL	73	1.6712	.7464	.0874	1.0000	5.0000	1.4971 TO 1.8454
FIXED EFFECTS MODEL			.7385	.0864			1.4989 TO 1.8436
RANDOM EFFECTS MODEL				.1470			-.1961 TO 3.5386

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE 0.0257

Tests for Homogeneity of Variances

Cochrans C = Max. Variance/Sum(Variances) = .7266, P = .004 (Approx.)
Bartlett-Box F = 6.545 , P = .011
Maximum Variance / Minimum Variance 2.658

- O N E W A Y - - - - - - - - - - - - - - - -

Variable V17 AFTER DELIVERY REJECTS
By Variable V113 MULTINATIONAL

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.7717	.7717	3.1013	.0825
WITHIN GROUPS	71	17.6667	.2488		
TOTAL	72	18.4384			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
Grp 1	25	1.2000	.4082	.0816	1.0000	2.0000	1.0315 TO 1.3685
Grp 2	48	1.4167	.5392	.0778	1.0000	3.0000	1.2601 TO 1.5732
TOTAL	73	1.3425	.5061	.0592	1.0000	3.0000	1.2244 TO 1.4605
FIXED EFFECTS MODEL			.4988	.0584			1.2261 TO 1.4589
RANDOM EFFECTS MODEL				.1102			-.0581 TO 2.7430

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE 0.0159

Tests for Homogeneity of Variances

Cochrans C = Max. Variance/Sum(Variances) = .6357, P = .099 (Approx.)
Bartlett-Box F = 2.259 , P = .133
Maximum Variance / Minimum Variance 1.745

- O N E W A Y - - - - - - - -

Variable V16 ASSEMBLY LINE REJECTS
By Variable TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	.4126	.2063	.3638	.6963
WITHIN GROUPS	70	39.6970	.5671		
TOTAL	72	40.1096			

Variable V16 ASSEMBLY LINE REJECTS
By Variable TYPE

MULTIPLE RANGE TEST

TUKEY-HSD PROCEDURE
RANGES FOR THE 0.050 LEVEL -

3.39 3.39

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
0.5325 * RANGE * DSQRT(1/N(I) + 1/N(J))

NO TWO GROUPS ARE SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

- O N E W A Y - - -

Variable V17 AFTER DELIVERY REJECTS
By Variable TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	2	.0141	.0071	.0268	.9736
WITHIN GROUPS	70	18.4242	.2632		
TOTAL	72	18.4384			

Variable V17 AFTER DELIVERY REJECTS
By Variable TYPE

MULTIPLE RANGE TEST

TUKEY-HSD PROCEDURE
RANGES FOR THE 0.050 LEVEL -

3.39 3.39

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
0.3628 * RANGE * DSQRT(1/N(I) + 1/N(J))

NO TWO GROUPS ARE SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

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