DETERMINING THE CRITICAL ELEMENTS FOR PRODUCING QUALITY PRODUCTS IN A MANUFACTURING ENVIRONMENT

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By

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I am submitting herewith a dissertation written by L. Paul Dreyfus entitled "Determining the Critical elements for Producing Quality Products in a Manufacturing Environment." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. with a major in Business Administration.

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DEDICATION

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ABSTRACT

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The study investigated the relationship between 14 elements (variables) identified in literature as critical for the production of high quality products. The fourteen elements (variables) involved in this study are: strategy emphasizing product quality, management participation, attitude toward risk, communications, hierarchical organizational structure, statistical quality control, management of materials, supplier relations, concurrent engineering, design for manufacturability, experiment of design, worker empowerment, worker involvement, and training and education. A researcher developed questionnaire was used to examine the significance of the 14 factors for producing a quality product in manufacturing.

The population for the study was selected in a two-phase process. Phase I consisted of a random sample of 2,000 members drawn from a section of American Society for Quality Control's (ASQC), who met the criteria of members

who represented manufacturing facilities (SIC codes between 20-39), classified themselves as mid-level managers, and provided a business mailing address. Questionnaires were mailed to the first manager selected for each facility who met the criteria. Dillman's four-phase mailing method was used to optimize the response rate.

Eight variables; communications, design for manufacturability, strategy emphasizing product quality, materials management, concurrent engineering, worker empowerment, statistical quality control, and attitude toward risk, were determined to be statistically significant. The amount of variance in product quality explained by the eight significant variables was .51182.

In Phase II, a subsample of manufacturers of high quality products was selected based on the Baldrige Award criteria, analysis addressed whether the 14 variables were statistically significant in manufacturing of a high quality product. Five variables were statistically significant and their rank order of importance are: communication, design for manufacturability, management of materials, strategy emphasizing product quality, and training and education. Amount of variance explained was .19488.

For Phase III, factor analysis was used to summarize the patterns of correlations among the 14 variables and reduce the number of observed variables to five suprafactors. They are Personnel Environment, Strategic Planning, Operational Control and Process Improvement, Product Design and Development, and Hierarchical Organizational Structure.

Four of the suprafactors; Personnel Environment, Strategic Planning, Operational Control and Process Improvement, Product Design and Development, were determined to be statistically significant and are presented in rank order of significance. The amount of variance in product quality explained by the four suprafactors was .16804.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GTD	Grand Total Dependent Variable
WI	Worker Involvement
Strat	Strategy Emphasizing Product Quality
TE	Training and Education
MP	Management Participation
WE	Worker Empowerment
RISK	Attitude toward Risk
Comm	Communications
HMgmt	Heirarchical Management Structure
SQC	Statistical Quality Control
MM	Materials Management
SRel	Supplier Relations
CEng	Concurrent Engineering
EOD	Experiment of Design
DM	Design for Manufacturability

CHAPTER I

INTRODUCTION

Beginning in the 1940s and continuing through the 1960s, the United States (U.S.) served as the world's standard for product quality, enjoying a position of unprecedented advantage in both productivity and quality (McClenahen & Pascarella, 1987). During the 1970s and early 1980s, the U.S.'s quality status declined when other countries, notably Japan and West Germany, introduced competitive, low cost, highly technical products of superior quality into the world marketplace (Buffa, 1984; Wheelwright & Hayes, 1985).

United States corporate management's awareness of the need to produce high quality products increased dramatically during the mid 1970s through the 80s (Zeithaml, Parasuraman, & Berry, 1990). United States managers have become increasingly aware that, for a business to survive and gain a competitive advantage in today's marketplace, quality is a key ingredient (Porter, 1985).

Attaining and maintaining the ability to produce quality products has proven difficult and elusive for most American companies (Spencer, 1994). Reasons given for the difficulty include lack of management training, insufficient product/process knowledge, and lack of long-term commitment to a quality improvement program (Adler, 1993). By its very nature, maintaining high product quality standards is a long-term, continuous, never ending process (Adler, 1993).

Malcolm Baldrige Award for Quality

In recognition of the importance of product quality and quality management, the Malcolm Baldrige Award (Public Law 100-107) was created by Congress in 1987 (Heaphy & Griska, 1993). The purposes of the Baldrige National Quality Award program are to promote:

1) awareness of quality and its impact on competitiveness;
2) understanding of the requirements for excellence in quality;
3) sharing of information on successful strategies and benefits that can be derived from excellence in quality among companies. (Heaphy & Gruska, 1993; Miller, 1994)

To obtain a high Baldrige Award score requires a systematic approach to product quality improvement as well as the participation of everyone in the organization (Garvin, 1991). Proponents of the philosophy recognize that there are many different paths to reach the goal of producing high quality products. Each company is free to choose the method(s) to achieve the ability to manufacture quality products.

Companies competing for the Baldrige Award must have "customer-oriented" quality programs led by senior management, a high level of employee involvement and understanding of internal processes, and "management by fact" rather than by "instinct" or "feel" (Garvin, 1991). This implies that management must have extensive process knowledge, continuous training, and meaningful data collection in order to make informed decisions concerning the products that are being produced.

The Baldrige Award has emerged as an agent of change, helping companies understand why and how product quality improves competitiveness (Hart & Schlesinger, 1991). It also gives companies practical tools that can be used to drive a quality initiative (Hart & Schlesinger, 1991). Motorola, using the Baldrige criteria to improve product quality, developed systems to measure customer and supplier relationships, which resulted in improved quality and service at lower cost (Moody, 1992). Miller (1994) believed that the Baldrige Award has been a factor in raising product quality in the U.S.

Quality Defined

Reeves and Bednar (1994) asserted that different definitions of "quality" have yielded inconsistent results. Quality has been defined as conformance to requirements (Crosby, 1979), fitness for use (Juran, 1974, 1988), loss avoidance (Taguchi, cited in Ross, 1988), and meeting and/or exceeding customers' expectations (Gronroos, 1990; Parasuramand, Zeithami, & Berry, 1985).

Crosby (1979) defined quality as "conformance to requirements" (Crosby, 1979). In his definition, Crosby challenged five erroneous assumptions directed at product quality. First, he indicated that quality was not goodness, or luxury, or weight, but conformance to required measurements of a particular product. Secondly, he challenged the assumption that quality was intangible and could not be measured. He contended that a credible measure of quality was money and that this was determined by whether there was a market for the product. The third erroneous assumption was that there was an "economics" of quality based on a logic that product quality may exceed its worth for the company. Crosby asserted that it was cheaper to do things right the first time. He also challenged management's contention that all the problems of quality are originated by the worker, particularly those in the manufacturing area. The fifth erroneous assumption he challenged was that quality originates in the quality department and it cannot be inspected into a product.

Product quality as defined by Juran (1992) was "fitness for use" and relates to product features that respond to customer needs and are free from deficiencies. This implies that product features are measurable and lack quality if a product is not fit for its intended use and is not in conformance. Again, lack of conformance or fit increases cost to the customer by requiring replacement or repair of the product.

Taguchi defined quality in relation to the product's useful life expectancy. "Quality is related to the loss to society caused by a product during its life cycle. A truly high quality product will have a minimal loss to society as it goes through this life cycle" (Ross, 1988, p. 1). Taguchi developed a method called the "loss function" to calculate the loss to society of a product (Ross, 1988). This method recognizes the customer's desire to have products that are consistent (minimal variation from part to part) and that meet the producer's objective of low cost. This definition implied that, relative to a company's warranty, customer dissatisfaction, and repair, minimal cost was incurred by the consumer during the product's life.

The definition of product quality as meeting and/or exceeding customers' expectations has gained acceptance as the economic importance of the service sector has increased (Reeves & Bednar, 1994). Gronroos (1990) asserted "it should always be remembered that what counts is quality as it is perceived by the customer" (p. 37). Buzzell and Gale (1987) defined quality as "whatever the customers say it is, and quality of a particular product or service is whatever the customers perceive it to be" (p. 111). Most operations management scholars continue to define product quality as conformance to requirements (Reeves & Bednar, 1994).

Combining these definitions of quality, four implied or stated assumptions are:

1. The product satisfies customers' need(s), therefore it is marketable (Juran, 1992; Crosby, 1979, Taguchi (cited in Ross, 1988));
2. product quality is measurable (Juran, 1992; Crosby, 1979; Taguchi (cited in Ross, 1988));
3. the product is free of defect(s) (Juran, 1992; Crosby, 1979; Taguchi (cited in Ross, 1988)); and
4. with product nonconformance, a financial loss is incurred by both the manufacturer and the customer (Juran, 1992; Crosby, 1979; Taguchi (cited in Ross, 1988))

Contribution of the Research

The purpose of this research is to identify the critical variables (factors) and the interrelationships between the variables that result in product quality in a manufacturing environment. In addition to identifying significant variables, this research will determine the relative importance of the variables by rank ordering both the variables and the groups that the variables form.

A review of the research and trade literature found an abundance of variables (factors) resulting in product quality in manufacturing case studies that the authors have generalized to the manufacturing industry as a whole (Juran, 1992; Schonberger, 1986; Stahl & Bounds, 1991). However, Dean and Bowen (1994) found that there were limited empirical studies that assess what variable(s) were critical to maintaining quality production.

If the U.S. is to continue to be a globally viable competitive leader, it must be able to produce competitive, marketable, and high quality products (Reeves & Bednar, 1994). Identification of the variables in product quality will allow managers to knowledgeably plan for increased product quality improvements (Dean & Bowen, 1994). With identification of significant variables relating to product quality, managers of product quality programs can evaluate the present level of each variable within their manufacturing environment. They can then knowledgeably allocate their company's finite resources to improve production of quality products. This improvement in product quality should, in turn, lead to increased manufacturing productivity, decreased costs of production and a competitive advantage (Benson, Saraph, & Schroeder, 1991).

Research Questions

This study is designed to address the following questions critical to product quality in a manufacturing environment:

1. Of 14 variables identified in the literature, which are significant in the production of a quality product in a manufacturing environment?

2. What is the relative importance of each of the individual variables?

3. How much variation in product quality is explained by these variables?

Other questions that will be addressed, using the Baldrige Award to select a subsample of high quality producers, are:

4. Of 14 variables identified in the literature, which are significant in the production of high quality product(s) in a manufacturing environment?

5. Which variables group together to create suprafactors?

6. Which suprafactors have a significant effect on production of high quality product(s) in a manufacturing environment?

7. What is the relative importance of the suprafactors?

8. How much variation in product quality is explained by these suprafactors?

These research questions will be answered from results of a randomized cross-sectional survey conducted with managers of firms in manufacturing.

CHAPTER II

LITERATURE REVIEW

An intensive review of the manufacturing product quality literature was used to identify elements considered important for producing quality products. Fourteen elements were identified and were selected for this research as potentially significant factors in producing a quality product. Criteria for selection of each of these elements was 1) designated by seven or more authors as crucial for quality product production or 2) consistently indicated as having an impact on product quality. The following sections are used to indicate why each element was selected and the impact of the element on product quality. Issues in measuring product quality in manufacturing were also identified and addressed in this review in terms of conformance, external failure, and reliability.

Elements of Product Quality in Manufacturing

There is general agreement regarding the variables that should be present for a quality product (Imai, 1987; Schonberger, 1986; Shingo, 1990; Susman & Chase, 1989); but there is limited empirical evidence to support these assertions (McCutcheon & Meredith, 1993; Young & Selto, 1991). Product quality research has been qualitative, based on limited interviews and the researcher's observations of participants (Anderson, Cleveland, & Schroeder, 1989; DeMeyer & Ferdows, 1991; Neely, 1993). Their conclusions need to be validated with quantitative methodology (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990).

Table 1 lists variables and the corresponding authors that supports each variable as crucial to producing a quality product. Each variable is briefly described here.

Strategy Emphasizing Product Quality

"Strategy is a set of important decisions derived from a systematic decision-making process conducted at the highest levels of an organization" (Anderson, Schroeder, & Cleveland, 1993, p. 86), which guides and focuses the corporate functional areas. The first principle of strategy is to deliver value to customers (Ihmae, 1989). The company's strategy must focus on internal resources, assessment of competitors, and forecast of future customer motives and behavior to gain a competitive advantage (Gluck, Kaufman, & Walleck, 1980; Porter, 1985; Skinner, 1974a) that will help secure its future viability (Henderson, 1989).

Table 1

Proposed Variables to Produce Quality Products in Manufacturing

Elements	Author*
Strategy Emphasizing Product Quality	2, 17, 29, 30, 37, 38, 40, 52, 56, 74, 78, 82
Management Participation	2, 6, 10, 21, 26, 36, 40, 55, 72
Attitude Toward Risk	7, 9, 41, 71
Communications	1, 16, 18, 43, 77, 82, 84
Hierarchical Organizational Structure	12, 14, 19, 20, 35, 48, 70, 71
Statistical Quality Control	22, 27, 46, 50, 54, 59, 71
Materials Management	19, 24, 39, 42, 45, 57, 79
Supplier Relations	23, 24, 28, 33, 34, 71, 76
Concurrent Engineering	16, 22, 25, 41, 44, 71, 83
Experiment of Design	11, 13, 31, 60, 71, 75, 83
Design for Manufacturability	3, 16, 17, 33, 36, 58, 71, 82, 83
Worker Involvement	2, 5, 15, 51, 53, 71, 73
Training and Education	16, 22, 40, 43, 49, 77, 80, 84
Worker Empowerment	4, 8, 9, 32, 47, 71, 72

See Table 1 notes for authors' names.

Table 1 Notes:

Authors cited:

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1. Adler (1993)
2. Anderson, Cleveland, & Schroeder (1989)
3. Anderson, Schroeder, & Cleveland (1993)
4. Andrews (1992)
5. Bennis (1987)
6. Bennis (1989b)
7. Bennis (1989c)
8. Bennis (1991)
9. Benson (1990)
10. Benson, Saraph, & Schroeder (1991)
11. Bhote (1992)
12. Buch (1992)
13. Byren & Taguchi (1987)
14. Chung (1994)
15. Ciampa (1989)
16. Clark (1989)
17. Cleveland, Schroeder, & Anderson (1989)
16. Corbett (1986)
17. Coughlan & Wood (1992)
18. Davis & Olson (1985)
19. Dumond & Newman (1990)
20. Drucker (1988a)
21. Drucker (1988b)
22. Drucker (1990)
23. Ebrahimpour & Manguameli (1990)
24. Ellram (1990)
25. Galbraith (1991)
26. Garvin (1987)
27. Gedye (1968)
28. Giunipero & Law (1990)
29. Gluck, Kaufman, & Walleck (1980)
30. Gray (1989)
31. Gunter (1991)
32. Gyllenhammar (1977)
33. Handfield (1993)
34. Handfield & Pannesi (1992)
35. Hardy (1993)
36. Hayes (1981)
37. Henderson (1989)
38. Ihmae (1989)
39. Ishikawa (1985)
40. Juran (1991)
41. Juran (1982)
42. Kathawala & Nauo (1989)
43. Kinnie, Staughton, & Davies (1992)
44. Krubasik (1988)
45. Lascelles & Dale (1989)
46. Maskell (1989a)
47. Maskell (1991)
48. Mathys & Burack (1993)
49. McClenahen & Pascarella (1987)

50. McKee (1989)
51. McKenna (1991)
52. Minor, Hensley, & Wood (1994)
53. Moskal (1991)
54. Pall (1987)
55. Pearson, (1989)
56. Porter (1985)
57. Reack, Landeros, & Lyth (1992)
58. Renquist (1991)
59. Rohan (1989)
60. Ross (1988)
70. Schein (1989b)
71. Schonberger (1986)
72. Senge (1990a)
73. Skinner (1971)
74. Skinner (1974a)
75. Taguchi & Clausing (1990)
76. Toelle & Tersine (1989)
77. Verepej (1991)
78. Vickery (1991)
79. Watts, Kee, & Hahn (1992)
80. Webber (1993)
81. Wheelwright & Clark (1992)
82. Wheelwright & Hayes (1985)
83. Whitney (1988)
84. Wriston (1990)

Product quality is recognized as a major source of competitive marketplace advantage (Juran, 1991) and "lack of product quality is a millstone around the neck of management" (Skinner, 1969, p. 137). The goal is to integrate product quality with the company's business strategy (Skinner, 1969; Wheelwright & Hayes, 1985). Strategic planning cannot achieve its full potential until it is positioned, aligned, and integrated with other functional areas within the company (Anderson, Cleveland, & Schroeder, 1989; Gray, 1989). Gunn, national director of the Manufacturing Consulting Group at Arthur Young, suggested that agreement on a manufacturing strategy, development of management teams, and encouragement of employee participation are critical for success in quality product manufacturing (Skinner, 1988).

Studies have shown that companies with a strategic manufacturing plan which emphasizes product quality had a larger return on investments (Cleveland, Schroeder, & Anderson, 1989; Minor, Hensley, & Wood, 1994). Vickery's (1991) study measured business performance, product quality, and the degree of match or fit of the company's business strategy to its competitive environment. Vickery found that companies with business strategies that did not match their manufacturing capabilities had lower financial performance and smaller or declining market share.

Management Participation

Management's participation is required to produce a quality product (Pearson, 1989). This requires consistency of direction, long term management commitment, resource allocation, management and worker participation to be successful. Hayes (1981) argued that high product quality can be achieved by a management system that has the support of management. Drucker (1988b) believed that management's job is to support and enable each member of the organization to grow and develop. Juran (1991) stated that "having observed a great many companies in action, I am unable to point to a single instance in which stunning quality results were achieved without the active and personal leadership of upper management (manager/leader)" (p. 12).

Effective manager/leaders create an environment for innovation, flow and sharing of new ideas, and continuous improvement (Drucker, 1988a). The chief objective of a manager/leader is the creation of a human community, held together by the work bond, for a common purpose.

Manager/leaders are teachers or facilitators, helping everyone in the organization to gain insight into the firm's present position and future direction (Senge, 1990a). The successful manager/leader's real genius lies, not in personal achievements, but in unleashing other people's talent.

Six areas of competence shared by successful managers/leaders are: 1) compelling vision; 2) ability to create a climate of trust, 3) reliability; 4) integrity; 5) product/process competency; and 6) creative successes, often from failure (mistakes) (Bennis, 1989b). This type of manager/leaders creates a healthy, empowering environment so others can achieve success (Bennis, 1989a). They define formally and/or informally the firm's mission statement by their deeds and actions. Studies have determined that, if an organization is to achieve superior product quality, management must be supportive of the effort (Benson, Saraph & Schroeder 1991; Garvin 1987). Anderson, Schroeder, and Cleveland's (1993) study determined that only half of the executive managers identified manufacturing management as taking an active leadership role in developing business strategy.

Attitude Toward Risk

There is a general belief that risk-taking should be supported by managers and workers at all levels in the organization. Organizations that encourage thoughtful dissent make better decisions (Bennis, 1989c). Moreover, the greater the initial disagreement among group members, the more accurate the resulting decision(s). Effective manager/leaders reward dissent and also encourage it (Bennis, 1989b).

If a corporation is to experience continuous product quality improvement, risk-taking should be encouraged and supported (Juran, 1982). There is a positive correlation between workers' trust of management and their willingness to take risks (Benson, 1990). No studies could be found which examine employees' attitude toward risk and its influence on product quality.

Communications

Successful product quality in manufacturing requires information to flow freely and easily. Each time information is transferred through a layer of management, a process of filtering, interpreting, and routing takes place, which may distort the original meaning of the information (Davis & Olson, 1985). The more times information is transferred, the less clear the original meaning will become.

Open, direct communication throughout a company facilitates the flow of information, ideas, and decision making (Wriston, 1990). Communication is the "glue" that allows managers and workers in all corporate functional areas to see how their decisions and actions influence the success of the firm and lead to competitive advantages in the marketplace (Clark, 1989).

Kinnie, Staughton, and Davies (1992) determined that, when management assumed the responsibility for communicating a common task (producing a quality product) directly to all levels of the company, there was a higher probability of having a successful outcome. Verepej (1991) found that one key to Motorola's production of quality products was the ability to communicate the goals and expectations for each business unit to the workers. In the New United Motors Manufacturing study, communication was found to be essential in creating an atmosphere of trust and common purpose between workers and workers, and between workers and managers (Adler, 1993). This atmosphere helped build a consensus for important decisions affecting the plant's future.

Hierarchical Organizational Structure

Corporate management has traditionally viewed the organization in terms of a vertical or hierarchical structure. This type of organizational structure creates departmental boundaries that discourage employee interaction between departments and supports continuation of suboptimization of departments (Chung, 1994). Presently, organizational revolution to change this traditional hierarchical organizational structure is occurring, eliminating layers of management and reducing costs (Schein, 1989b). The organizations of the future are projected to be flatter (Drucker, 1988a). Schonberger (1986) suggested that there should be only four levels of management above line workers.

Organizations are adopting flatter organizational structures to improve customer response time, meet market demands and reduce managerial cost (Mathys & Burack, 1993). The more times information must be transferred, the less clear the original meaning becomes; consequently, flatter organizational structure facilitates improved communication (Davis & Olson, 1985). The fewer the levels of an organization, the easier and faster information reaches the intended recipient.

This type of business structure facilitates management across functional areas, employee empowerment, improved communication between functional departments, and elimination of unnecessary work (Chung, 1994). The main organizational structural effect of hierarchical restructuring has been the elimination of levels of middle management (Hardy, 1993). Buch (1992) determined that organizational downsizing has had a positive effect on product quality when companies have had active employee participation programs.

Statistical Quality Control

Statistical quality control (SQC) was developed over seventy years ago as a technique for inspecting manufactured parts without having to scrutinize each individual one (Gedye, 1968; McKee, 1989). The purpose of SQC is to identify where the quality and productivity of the entire process can be continuously improved (Drucker, 1990).

The principle statistical techniques used in quality control are: 1) frequency distribution; 2) sampling techniques; 3) control charts; and 4) statistical tests for reliability (Gedye, 1968). Statistical quality control tracks the variation from specification throughout the production process (Maskell, 1989a). Statistical quality control charts should be prominently displayed on the manufacturing floor so the manager can visually observe if a process is in control (Drucker, 1990; Schonberger, 1986). Once a process is under statistical control, its performance is predictable (Pall, 1987).

Thirteen months after Caterpillar's Mossville, Ill., diesel engine plant implemented SQC in 1982, defects were cut from 80 to 0.6 per 1000 parts (Rohan, 1989). The mean time between failures of machine tools was extended 125% and the mean time to repair machines was cut 33%.

Management of Materials

Rapid changes in the industrial environment, such as the introduction of automation, computer-aided-design/computer-aided-manufacturing (CAD/CAM) and just-in-time (JIT), as well as demands for increased product quality, have increased the need for all personnel to be concerned with control of materials (Kathawala & Nauo, 1989). Advancements in materials management concepts, techniques and practices require that modern material management professionals have different skills than their 1970s and 1980s counterparts (Reack, Landeros, & Lyth, 1992). These skills require broader backgrounds in both business and technical areas. Materials management plays an increased role in the success of today's companies in terms of product quality and corporate competitiveness (Watts, Kee, & Hahn, 1992). In the future, materials will represent an increasing percentage of total product costs and their control will be correspondingly more important than it is today (Dumond & Newman, 1990).

Crosby estimated that 50% of a company's quality nonconformances are caused by defective purchased material (Lascelles & Dale, 1989). Ishikawa (1985) suggested that at least 70% of product quality problems can be traced to defective purchased material. Lacelles and Dale's (1989) study found that a fundamental weakness in the communication linkage between materials managers and suppliers was a serious roadblock to quality products. Kathawala and Nauo (1989) and Ellram's (1990) studies determined that successful materials management result in a positive impact on the net profit and cash flow of a company.

Supplier Relations

As the number of highly specialized, complex products grows, organizations will find they are dependent on a few suppliers for their material requirements (Toelle & Tersine, 1989). Consequently, effective supplier relations will require a clear understanding of expectations, open communication and information exchange, mutual trust and a common direction (Ellram, 1990).

This long-term relationship complicates the supplier selection process. A long term focus implies not only that a current supplier's performance and capabilities are important, but that the supplier's potential and future direction must be congruent with the customer's long-term goals and objectives (Giunipero & Law, 1990).

Ellram's (1990) study determined that manufacturers' selection criteria for suppliers were financial health and technology capabilities. Ebrahimpour and Manguameli (1990) and Handfield and Pannesi (1992) identified on-time delivery, product quality, correct count, flexibility, and cost as criteria for evaluating suppliers.

Handfield's (1993) study determined that firms with close relationships with their suppliers had ten times less material rejected because of quality problems and experienced half the number of late deliveries. These firms shared product information and had three times the level of interaction with their suppliers than other firms.

Concurrent Engineering

The importance of reducing the product development cycle time cannot be overestimated. Because of the shorter life cycle of products, time-based competition has emerged as a potent business strategy (Clark, 1989). Meeting the challenge of launching a new product requires an integrated design and development approach in which the design processes are increasingly simultaneous (parallel) rather than sequential (Drucker, 1990).

Strategic product design requires that managers, designers and engineers learn and practice a discipline that integrates engineering, management of people, and business economics into the manufacturing process (Krubasik, 1988; Whitney, 1988). For this product design process to be successful, companies must facilitate communication between all involved functional areas, regardless of physical distance (Galbraith, 1991).

In Krubasik's (1988) study, Boeing's concurrent engineering effort resulted in their 767 airplane getting to market eight months ahead of Airbus's 310, thereby capturing a major percentage of the world market.

<u>Design for Manufacturability</u>

Design for manufacturing is the next step in getting a product to market. "You don't inspect quality into a product, you must build it in" (Hayes, 1981, p. 59). Hayes indicated that although this statement is true, a preliminary step before manufacturing a product is its design. Before quality is built in, manufacturability must be designed into the product.

Design for manufacturability is a strategic activity because it has more leverage in determining product quality than any other functional area (Renquist, 1991; Schonberger, 1986). Corbett (1986) found that approximately 70-80% of a product's total cost is determined at the design stage of its development. Whitney (1988), in a study of New United Motors Manufacturing, indicated that redesigning the assembly line was one of the critical factors in the company's success in producing high quality cars. The redesign had a substantial impact on the success of the strategic plan and management at both the firm and functional levels (Anderson et al., 1993). The goal of design for manufacturability is to simplify the product design and reduce the number of product components or parts. Redesign results in increased product quality, reliability, and customer satisfaction (Whitney, 1988). Designers who anticipate the assembly method can avoid the pitfalls that would require redesign or create problems on the factory floor (Wheelwright & Hayes, 1985).

Coughlan and Wood (1992) defined the features of a manufacturable product:

> A manufacturable product has few production line stoppages, low rework costs and few after sales problems. It is safe to produce, workmanship is high and production costs low. The product is easy to fabricate and handle, while the parts and assemblies are easy to kit, handle, inspect and test. Such simplicity requires a reduction in the number of parts, the development of foolproof assemblies and a simplified assembly process, use of common components across product families, avoidance of tolerances that exceed process capabilities and use of modular options. (p. 64)

Two indicators used by Handfield (1993) for measuring the degree of product manufacturability were: 1) percentage of defects per unit and 2) number of engineering change notices that occur per month per part. For example, Nippondenso used the concepts of design for manufacturability to develop a jigless model radiator for cars (Whitney, 1988). The entire radiator just snaps together by hand, resulting in time and labor savings.

Experiment of Design (EOD)

In the past, product designers and manufacturing engineers used their intuition and experience to understand the relationship between different attributes to produce quality products (Whitney, 1988). Today, in determining and correcting product quality problems, pre-manufacturing experimentation is less costly than waiting until the product is on the manufacturing line (Bhote, 1992). Benefits of EOD are reduced variability of parts and/or products, lower cost of manufacturing, higher product quality, increased manufacturability, and reduction in factors that cause system failures (Gunter, 1991). Results of EOD are fewer product defects and less scrap, rework, and warranty work. The use of EOD leads to increased profits, customer satisfaction and greater market share (Ross, 1988).

Experiment of design of a product will reduce the loss to society associated with every product that reaches the consumer (Byren & Taguchi, 1987). The loss to society is composed of: the production cost; the customer related costs, such as consumer's dissatisfaction; added warranty cost to the producer; lost market share; and the loss of a company's reputation for quality. The 'minimization of losses to society' strategy will encourage uniform products and, therefore, minimize product quality variation and costs at the points of production and consumption (Ross, 1988).

Taguchi and Clausing (1990) demonstrated how Ford Motor Company reduced complaints, scrap, and warranty work by using EOD to reduce the noise level in its cars' transmissions. Experiment of design is being used at

Richard Medical to speed a new hip joint adhesive to market (Dreyfus, 1992).

Worker Empowerment

Empowerment involves the workers' sense that they are at the center of things and are contributing to the organization's success (Bennis, 1991). An empowered work force is committed and is most evident when employees feel significant, value learning and competence, feel part of a community, and find work exciting (Bennis, 1989a, Bennis, 1990a). Empowered organizations are characterized by trust and system-wide communication (Bennis, 1990a).

Companies choosing to increase worker empowerment must be consistent and persistent in implementation of a program if workers are to believe in and trust company's management (Benson, 1990). Whatever shape the future ultimately takes, the organizations that will succeed financially are those that seriously believe that their sustainable, competitive advantage is based on the development and growth of their workers (Andrews, 1992). Results of empowerment programs are less employee turnover, less worker compensation claims, and increased profits (Andrews, 1992).

Gyllenhammar's (1977) study of the decision-making process of empowered workers demonstrated that the decision-making process took more time, but that the decisions were more readily accepted and more rapidly implemented. Workers at the Honda plant at Marysville, Ohio, were given responsibility for every car's quality at their workstations and the authority to stop the line if there was a problem. By 1990, the quality of Honda Accords at the Marysville plant was nearly equal to the Accords made in Japan (Maskell, 1991).

Worker Involvement

Most corporate leaders have traditionally viewed workers as adversaries led by fear and intimidation (Bennis, 1987). In the past, workers followed because of feelings of obligation and guilt (Bennis, 1990a). This view is changing: a survey done by *Industrial Week* and Wyatt Company indicated that management was embracing the concepts of worker involvement (McKenna, 1991). Moskal (1991) indicated that the real motivation for changes in management's attitude toward worker involvement is the global competitive challenge that requires higher quality, productivity, customer service, and cost reduction. Attitude change is not easy because the people segment of organizational strategy is the most difficult to influence (Skinner, 1971). Skinner indicated that middle management and labor have the greatest resistance to worker involvement. Middle management is often not convinced that management has made a long-term commitment to this style of management. Labor, according to Moskel (1991), believes that management does not care what happens to them. Leadership's challenge is to make policies that meet the needs of organization and the expectations of the employees (Anderson et al., 1989).

A study conducted by Wyatt Company found that the greater the level of job training provided by the company, the higher the level of employee involvement in quality improvement (Moskel, 1991). Ciampa's (1989) study showed that efforts to improve product quality without employee involvement resulted in mediocre performance.

Training and Education

In the U.S., firms are spending over $25 billion a year to educate workers in basic educational skills -- reading, writing, and mathematics -- and an additional $40 billion annually on job-training programs (McClenahen & Pascarella, 1987). Businesses absorb the expenses of education and loss of production while their employees learn these new skills.

Firms must provide extensive training on how to manage for quality, make improvements, and utilize the tools and techniques for improving quality (Juran, 1991). In the 1990's and beyond, knowledgeable workers are the only real capital corporate asset, and they provide a sustainable competitive advantage (Clark, 1989; Verepej, 1991). Knowledgeable workers have access to vital information, take pride in their craft and understand the value of their unique contribution to the success of the company (Wriston, 1990). They are the key to generating real wealth through new ideas, innovation, and change.

Knowledge resides in people and in the organizations they inhabit. Therefore management, by creating an environment that allows workers to learn from each other as well as from their customers, suppliers and business partners, can increase the company's assets. The chief management tool that makes learning happen is conversation (Webber, 1993).

Kinnie, Staughton, and Davies (1992) found that reasons given for failure of manufacturing systems were mostly "non-technical" in nature. The main problems cited were lack of worker education, training, and management support. Drucker (1990) indicated that Herman Miller's success in achieving zero-defects quality and high productivity resulted from its continuous training efforts for all employees.

Criteria for Measuring Level of Success in Producing a Quality Product in Manufacturing

From a review of the literature, three indicators (variables) were identified that, if measured, will assess the level of product quality in manufacturing. These are: product conformance, external failures leading to product warranty and liability claims, and product reliability. Table 2 lists the criteria and the authors who support the criteria for measurement of product quality in manufacturing. An explanation of each variable follows.

Table 2

Criteria for Assessing Level of Success of Product Quality in Manufacturing

Criteria	Author
Conformance	1, 2, 3, 6, 8, 9, 10
External failures	2, 5, 7, 8, 9, 10
Reliability	3, 4, 5, 6, 9, 10

Authors:

1. Gilbert (1991)
2. Bounds and Pace (1991)
3. Garvin (1987)
4. Schonberger (1986)
5. Feigenbaum (1983)
6. Drucker (1990)
7. Armistead and Clark (1991)
8. Pall (1987)
9. Juran (1992)
10. Crosby (1979)

Conformance

Conformance is the degree to which a product's design and operating characteristics meet established standards (Garvin, 1987b). Lack of conformance is measured by the number of defective products that must be scrapped or reworked to meet required specifications. A product's scrap and rework are a key measurement because they represent success or failure of the process (Maskell, 1989b). Defects are not free. Somebody makes defects and gets paid for making them; somebody must correct defects and also gets paid (Gitlow & Hertz, 1983). The cost of scrap and rework has a direct impact on the financial indicators of product quality. High product quality reduces cost of scrap and rework and increases system productivity.

Measurement of lack of conformance is calculated by summing frequency of defect and dividing by the total number of units produced during a specific period of time (Juran, 1992). Measurement of conformance usually involves design specification expressed as a target value with accepted upper and lower limits. Product quality is considered adequate if it stays within these defined limits (Ross, 1988).

External Failures Lead to Warranty and Liability Claims

High quality manufacturers have less service and warranty work in the field resulting in reduced labor costs and time spent on service work, as well as greater customer satisfaction with the product (Inman & Mehra, 1991). Customer satisfaction with product quality may be measured by the number of complaints and service calls and by measuring the percentage of repeat sales to existing customers (Maskell, 1989a).

The cost of liability exposures and the management of product risk is the biggest threat facing managers in manufacturing (Howard, 1991). Eisenberg (1991) stated at the first International Symposium on Risk Management at Toyama University that "liability costs have hindered the competitiveness of U.S. companies in the world marketplace" (p. 13). Of all the hidden costs in manufacturing, few are as high as those exacted by the legal system in product liability litigation (Grant, 1993).

Legislators are sensitive to the public's concern over product quality, product safety and meaningful warranty statements. Such concerns have been translated into laws and regulations that escalate product liability risks borne by manufacturers (Vinson & Heany, 1977). New York has introduced legislation to limit product liability because present tort law is forcing manufacturing businesses out of the state (Dauer, 1993).

Defective products may generate legal liabilities, potentially undermining the firm's profitability (Viscasi & Moore, 1993). Product liability should promote efficient levels of product quality and safety, but liability efforts may depress innovations (Howard, 1991). Locke (1990) indicated that liability exposure has negatively influenced research and development of innovative new products because of the financial risk to the companies.

The dramatic effects of liability exposure can be seen in Shapiro's (1992) study of the light aircraft manufacturing industry in the U.S. In 1979 there were 17,000 light aircraft produced by the three leading manufacturers, Piper, Beechcraft, and Cessna. By 1990 the total annual production from Piper and Cessna was 1,021 new aircraft; Beechcraft was no longer in business. Total industry employment dropped from approximately 20,000 in 1979 to under 2,000 by 1990 (Shapiro, 1991, 1992). Defending against claims cost a total of $27 million for both Piper and Cessna in 1990 (Shapiro, 1992).

Product Reliability

Reliability of a product "reflects the probability of a product malfunctioning or failing within a specified time period" (Garvin, 1987b, p. 106). According to Garvin, reliability of manufactured products can be measured, using mean time to first failure, mean time between failures, and/or failure rate per unit times.

The level of importance placed on reliability can be seen in the luxury car market. Toyota's Lexus, Honda's Acura and Nissan's Infiniti cornered 14% of the U.S. luxury car market in 1990 (Taylor, 1990a). These Japanese car manufacturers succeeded in selling the concept that their cars possessed exceptional product quality and reliability. Lack of high reliability results in an unhappy customer, as well as increased repair calls, high scrap and rework rate, and low worker morale.

The company that manufactures a high quality product compared to its competition, will have its reputation enhanced and customers will have a favorable perception of the firm (Deming, 1981-1982). The results are unlimited future possibilities to capture a greater market share.

CHAPTER III

METHODOLOGY

A survey using a researcher developed questionnaire was used to examine whether 14 factors, identified by review of literature, are significant in producing a quality product in manufacturing. These factors, independent variables in this study, are: strategy emphasizing product quality, management participation, attitude toward risk, communications, hierarchical organizational structure, statistical quality control, materials management, supplier relations, concurrent engineering, experiment of design, design for manufacturability, worker involvement, training and education, and worker empowerment. The dependent variable of this study was product quality. Product quality was developed for this study as a composite based on measurements of conformance to specifications, external failures, and reliability.

Hypotheses and Research Questions

Review of literature resulted in the identification of 14 factors considered important to product quality in manufacturing. However, literature did not provide a clear and comprehensive picture of the interdependence and interactions of these variables. This study was conducted to examine the interrelationship among these variables.

The hypothesis addressed was:

H_o : The 14 proposed variables are equally significant among manufacturers. (3.1)

Each of the derived hypotheses was tested at the 0.05 level of significance.

Further analysis focused on Research Question #2: What is the relative importance of each of the individual variables? and #3: How much variation in product quality is explained by the significant individual variables?

Additional analyses were performed on a subsample that was identified by using the Baldrige Award criteria to determine which manufacturing plants were producers of high quality products. The purpose of this section of the research was to examine the interrelationship among the 14 variables of only the manufacturers of high quality products.

The hypothesis addressed was:

H_c : The 14 proposed variables are equally significant among manufacturers of high quality products. (3.2)

In addition, the relative importance of each of the individual variables in a high quality manufacturing environment was addressed with Research Question #4: What is the relative importance of each of the individual variables?

Determination of the second order factors (suprafactors) in this research was exploratory in nature. This analysis focused on four specific research questions that directly related to the second order factors:

5. Which variables group together to create suprafactors?

6. Which suprafactors have a significant effect on production of a quality product(s) in a manufacturing environment?

7. What is the relative importance of the suprafactors?

8. How much variation in product quality is explained by these suprafactors?

Population and Sample

The population of the study was selected in a two-phase process. Phase I consisted of a random sample of 2,000 members drawn from a section of American Society for Quality Control's (ASQC), who met the criteria of members that represented manufacturing facilities (SIC codes between 20-39), classified themselves as mid-level managers, and provided a business mailing address. Questionnaires were mailed to the first manager selected for each facility who met the criteria. All of the respondents whose questionnaires were usable were included in the analyses to determine which of the 14 variables (Hypothesis 3.1) are significant in a manufacturing environment.

The Phase II sample, based on the Baldrige Award criteria to determine manufacturers of high quality products, was developed from the returned and completed questionnaires. Section I of the questionnaire was reviewed and scored; respondents receiving a Total High Quality Product score in the upper 40 percent comprised the phase II sample. The Baldrige Award criteria and how the criteria were used to calculate the score are explicated in the following section.

Baldrige Award Criteria for Assessing Companies

The focus of the subsample drawn from the total sample for this study was managers of high quality manufacturing facilities. Because the sample included a broad spectrum of manufacturing companies, the measurement procedure to qualify a company as a quality producer had to be able to compare all businesses equally. The Malcolm Baldrige Award was specifically designed to measure and compare a broad spectrum of businesses as quality producers. This section is used to explain the Baldrige point system for quality manufacturing and how the point system was adapted to qualify companies in this research as producers of high quality products.

Criteria established for the Baldrige Award are used to identify firms that produce "high" quality products (Brown, 1992). The Malcolm Baldrige Award criteria codify the principles of product quality and quality management. In addition, the criteria provide companies, both large and small, with a comprehensive framework to measure and assess their progress in both the manufacturing and service sectors. In effect, the Baldrige Award criteria have become the de facto business model and the standard for quality excellence for U.S. industry (Cortada, 1994; Myers, 1992). Cole (1991) stated that many companies are using the Baldrige Award criteria as a benchmark for their quality achievements and in setting goals for product quality improvements.

The Baldrige Award is divided into seven categories with varying point values that reflect the level of importance of a particular category in the total evaluation (Brown, 1992). The seven categories are: leadership (point value of 90); information and analysis (point value of 80); strategic quality planning (point value of 60); human resource development and management (point value of 150); management of process quality (point value of 140); quality and operations results (point value of 180); and customers' focus and satisfaction (point value of 300). The Baldrige Award criteria's seven categories have a maximum point value of 1,000.

For this study, questions in Section I were developed to represent the seven categories of the Baldrige Award. Scoring of each of the categories was also designed to parallel the point value assigned by the Baldrige Award.

Aggregation of Elements in the Subsample

The criteria for an element to be included as an independent variable were 1) designated by seven or more authors as crucial to production of a quality product or 2) consistently indicated as having an impact on product quality. However, few articles addressed how a specific variable might affect product quality.

Factor analysis was used to explore the interrelationships of the 14 elements selected for this research. The aggregating of these elements facilitated computational and data organization requirements. The common relationship structures or groupings that resulted from aggregation of elements by factor analysis were designated as suprafactors in this research. Further explanation of the method of determining these suprafactors is explained in the analysis of data section of this chapter.

Survey Questionnaire

A two-part questionnaire (see Appendix A) was developed to address elements in a manufacturing environment by review of literature identified as crucial in the production of a high quality product. Section I of the questionnaire (items 1-59, 74, and 76) was based on Baldrige Award criteria and used to determine which respondents qualified as producers of high quality products. The questions were designed so that the respondent used a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) to answer each question.

The Baldrige Award was used as a framework because it codifies the principles of product quality and quality management (Brown, 1992). It also provides companies, both large and small, with a comprehensive framework to measure and assess their progress in both the manufacturing and service sectors. Baldrige Award categories, category weightings, questionnaire items, and item values are indicated. Section I of the questionnaire incorporating Baldrige Award criteria is summarized in Table 3 and provides seven category scores.

Data relating to the Baldrige Award questions are interval data. Crocker and Algina (1986) suggested a scoring approach of taking the Likert score and dividing it by the number of intervals on the Likert scale used, i.e., 7,

Table 3

Baldrige Award Categories, Category Weighting, Category Items, and Respective Questionnaire Item Values

Baldrige Award Category	Category Weighting	Category Items	Questionnaire Item Value
Leadership	90	1,2,3,4,5, 6,7,8	11.25
Information and Analysis	80	9,10,11,12, 13,14,15,16	10.00
Strategic Quality Planning	60	17,18,19,20 21,22,23,24 25,26,27	5.45
Human Resource Development and Management	150	28,29,30,31 32,33,34	21.43
Management of Process Quality	140	35,36,37,38 39,40,74,76	17.50
Quality and Operations Results	180	41,42,46,47 48,49	30.00
Customer Focus and Satisfaction	300	50,51,52,53 54,55,56,57 58,59	30.00

to determine the question's fractional value. Blanks (no response to an item) would be coded as Missing. In each category, the question's factional value of the responses to category items would then to be multiplied by the item's weighting for that category. In a category, each question would be equally weighted. The seven category scores would then be summed for a total score. The maximum possible score for a manufacturing facility is 1,000. This score would occur with all positive responses to items 1-59, 74, and 76.

Section II of the questionnaire was developed to address the two hypotheses of the study (3.1 and 3.2). Questionnaire items 1, 2, 5, 8-10, 17-21, 23, 27-30, 40, 51, 53, 64-80, 87, 97-99, 105, and 106 were developed to evaluate the 14 independent variables in the study as critical to producing a quality product. Questionnaire items 41, 43-47, 85, 86, and 91-95, evaluating product conformance, external failures and product reliability, were used to develop a composite score of product quality. Product quality served as the dependent variable in the study. Tables 4 and 5 display each of these variables and items used to measure each.

Ordinal data from each variable was scored using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). When evaluation of selected variables required two or more questions, scores from the questions answered were summed and divided by the number of questions. This ensured uniformity of weights among variables. The questions in the survey questionnaire are numbered to facilitate identification of which questions relate to individual variables.

Table 4

Independent Variables and Respective Questionnaire Items

Independent Variables	Questionnaire Items
Strategy Emphasizing Product Quality	17, 18, 19, 71
Management Participation	8, 20, 68, 79
Attitude Toward Risk	72, 73
Communications	9, 10, 29, 30, 69, 70
Hierarchical Organizational Structure	105, 106
Concurrent Engineering	77, 97
Experiment of Design	64
Design for Manufacturability	67, 98
Statistical Quality Control	1, 87
Materials Management	27, 40, 74
Supplier Relations	23, 78
Worker Involvement	5, 21, 51, 80, 99
Training and Education	2, 28, 75, 76
Worker Empowerment	53, 65, 66

Section III of the questionnaire was developed to measure the quality success variables of conformance, external failures, and product reliability (questionnaire items 41, 43-47, 85, 86, and 91-95). The three variables

Table 5

Success Criteria, Dependent Variable and Questionnaire Items

Criteria	Dependent Variables	Questionnaire Items
Criteria for Judging Level of Success of Product Quality in Manufacturing	Conformance	43, 44, 45 91, 92, 93
	External Failures	46, 94 95, 47
	Product Reliability	41, 85, 86

were summed for a composite score of success of product quality. Success of product quality was used as the dependent variable in a series of regression analyses.

Validity of Research Instrument

Using Franz and Robey (1986) guidelines, six ASQC managers reviewed the original proposed instrument to determine if the objectives were met of maximizing readability, clarity, understandability, comprehensiveness, and elimination of ambiguities of the product quality measurements. Based upon the recommendations of these reviewers, the questionnaire was modified to place questions relating to the Baldrige Award criteria early in the questionnaire.

A second test of content validity was conducted with the redesigned questionnaire. Six members of the local ASQC group, who had not been previously exposed to the questionnaire, checked the revised questionnaire to determine if the objectives were met and to make recommendations to eliminate ambiguity and to maximize readability, clarity, understandability, and comprehensiveness. Minor sentence changes were suggested and the recommendations were incorporated into the final questionnaire.

The questionnaire was pilot-tested (late June, 1995) with the Memphis chapter of ASQC. Only one questionnaire per manufacturer was given to the companies represented at the meeting. Twelve questionnaires were distributed and eleven were returned by the end of the meeting. One respondent, whose first language was not English, asked if he could mail the questionnaire. It was not returned. Each respondent took between 15 and 25 minutes to complete the questionnaire. No respondents completing the questionnaires reported or demonstrated any problems answering any question.

Data Collection Method

Dillman's (1978) four-step method for mailed questionnaires was used to maximize the response rate. For mailing 1, 3, and 4, a cover letter was reproduced on

University of Memphis letterhead stationery with the appropriate mailing date and the signature of the researcher. An identification number, clearly visible to the respondent, was placed on the cover of the questionnaire. The cover letter, an ID-numbered questionnaire, and a reply envelope were placed into a second envelope containing the respondent's name and address.

The first step in Dillman's method was to send the questionnaire, return envelope, and the first cover letter to the randomly selected sample of 2000 on October 3, 1995 (see Appendix B for the cover letters). Exactly one week later, October 10, 1995, a postcard follow-up was sent to all the questionnaire's recipients. These postcards were preprinted, but had the individual recipient's name and address typed on one side and the researcher's signature on the other. The note on this postcard served two purposes: 1) it served as a written thank you for those who had already returned their questionnaires and 2) it served as a reminder to those who had not. Although these cards were not mailed at the same time as the initial batch of surveys, they were prepared for mailing at the same time as the initial batch. Although it increased the expense of administering the survey, this step was done to reduce confusion that might otherwise occur. Data entry was immediately focused upon using this method. Because all participants received the second mailing, trying to keep up with which questionnaires had not been returned did not have to be addressed at this time.

A second follow-up was mailed October 23, 1995, to 1,744 non-respondents. It consisted of a cover letter that informed individual managers that their questionnaire had not yet been received, and included a reiteration of the basic appeal from the original cover letter, a replacement questionnaire, and a return envelope.

The third and final follow-up was mailed to the remaining 1,620 non-respondents November 28, 1995, eight weeks after the original mailing. It consisted of a cover letter, another questionnaire, and return envelope.

A data collection logbook was kept. It contained coded numbers of recipients, dates when the questionnaires were sent, who responded, dates the responses were received, and the completeness of the responses.

Analysis of Data

Data analysis was performed using SPSS statistical software, version 4.1. Calculations were done on a 6420 VAX running a VMS operating system.

Armstrong and Overton (1977) suggested the "last respondent" method of estimating the non-response bias in mail surveys. Armstrong and Overton determined that the "last respondents" (wave three) were similar to the non-respondent. If there was no significant difference between wave one and wave three, the results of the total sample were considered representative of the general population.

Hypothesis (3.1) "The 14 proposed variables are equally significant among manufacturers." was tested using regression analysis on data from the total sample. Each of the independent variables was determined using individual scores of each of the 14 variables; the dependent variable (Success of Product Quality) was the composite of the summed scores of the three success measures -- conformance, external failures, and product reliability.

The results of the regression analysis were used to test Hypothesis #1: The 14 proposed variables are equally significant among manufacturers.; and address Research Question #2: What is the relative importance of each of the individual variables? The adjusted R^2 value was calculated to answer Research Question #3: How much variation in product quality is explained by the statistically significant individual variables?.

The form of the multiple regression equation is:

$$LSPQ = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \quad . \quad . \quad . \quad + \beta_{14} X_{14} + e \qquad (3.1)$$

where

LSPQ = Level of Success of Product Quality

X_1 = Strategy Emphasizing Product Quality

X_2 = Management participation

X_3 = Attitude Toward Risk

X_4 = Communications

X_5 = Hierarchical Organizational Structure

X_6 = Statistical Quality Control

X_7 = Materials Management

X_8 = Supplier Relations

X_9 = Concurrent Engineering

X_{10} = Experiment of Design

X_{11} = Design for Manufacturability

X_{12} = Worker Involvement

X_{13} = Training and Education

X_{14} = Worker Empowerment

are the independent (predictor) variables, X's, the unknown slope parameters are β's and e is the unexplained error associated with the model. The exact values of the β's are unknown, therefore an estimate (b) of the β's was calculated. The residual is defined as the difference between the actual Y value and its estimate ($\hat{Y}$). The determination of the values of b_o, b_1, . . . , b_{14} were calculated by minimizing the Sum of Squares Error (SSE) of the residuals. The form of the multiple regression equation for LSPQ ($\hat{Y}$) now becomes:

$$LSPQ = b_o + b_1X_1 + b_2X_2 + \ . \ . \ . \ + b_{14}X_{14} + e \qquad (3.2)$$

where b_o, b_1, . . ., b_{14} are the least squares estimates of β_o, β_1, . . . , and β_{14}.

The two assumptions that must be met to run multiple regression analysis are normal distribution of the errors in measurement and linear relationship between independent variables. The probability of encountering a non-normal distribution was reduced by randomly selecting the research subjects. The normal distribution assumption was examined by measuring skewness. A skew value of zero represents a perfectly normal distribution. The farther the absolute value of skewness is from zero, the greater the violation of normality found in the data.

The linear relationship between independent variables was determined by examination of the Pearson correlation coefficient. The r value was measured against the t distribution to determine if the linearity was significant.

As each variable was evaluated in the multiple regression equation, a new adjusted R^2 and its associated F-value was tested for significance. Because of the number of independent variables in the regression model, there may be a high degree of correlation between two or more of the independent variables (multicollinearity).

The hypothesis (3.2) and four research questions relating to high quality producers were addressed using both multiple regression and factor analyses. Only the respondents that were in the high quality producers subsample (upper 40%) were included in this analysis. The independent variables were based on individual scores for each of the 14 variables; the dependent variable (Level of Success of Product Quality) was based on the combined scores of the three success measures -- conformance, external failures, and product reliability.

The results of the multiple regression analysis was used to test the hypothesis for the 14 variables:

H_o : The 14 proposed variables are equally significant among manufacturers of high quality products.

Statistical determination of significance was set at the $p < 0.10$ level.

Review of literature identified these 14 variables as important in the production of high quality products. However, the literature offered no insight concerning the rank ordering of these variables. This study examined the complex interactions among these variables which, in turn, allowed the determination of rank order. The hypothesis regarding how these 14 variables are ranked is:

H_o : The 14 proposed variables are equally significant among manufacturers of high quality products.

or

H_o: $X_1 = X_2 = . . . = X_{14}$

where the individual factors are

X_1 = Strategy Emphasizing Product Quality

X_2 = Management Participation

X_3 = Attitude Toward Risk

X_4 = Communications

X_5 = Hierarchical Organizational Structure

X_6 = Statistical Quality Control

X_7 = Materials Management

X_8 = Supplier Relations

X_9 = Concurrent Engineering

X_{10} = Experiment of Design

X_{11} = Design for Manufacturability

X_{12} = Worker Involvement

X_{13} = Training and Education

X_{14} = Worker Empowerment

This statistical determination was made at the $p < 0.10$ level.

Factor analysis was used to examine the interrelationships among the independent variables. The underlying assumption of factor analysis with this research was that there are a smaller number than the 14 observed variables that are responsible for the covariation among the observed variables. Valid statistical inferences about the population from which the sample data was drawn require that assumptions of multivariate normality and linear relationships between independent variables be met. The procedures for testing these assumptions have been previously discussed.

The linear weights (b's) are the estimated factor loadings for each variable (Kim & Mueller, 1978). Factor loadings are equivalent to the correlation between second order factors and variables. The correlation between any two observed variables (X_i and X_j) was given by the multiplication of the two relevant factor loadings. The equation is:

$$r_{ij} = (b_{Fi}^{T}) \quad (b_{jF}) \qquad (3\text{-}3)$$

where

r_{ij} = is the correlation between two observed variables

b_{Fi} = is the loading factor for X_i and F, the common factor

b_{jF} = is the loading factor for X_j and F, the common factor.

Factor analysis was used to determine the minimum number of hypothetical factors that can account for the observed covariation due to some underlying common factor(s). Correlation coefficients were calculated to measure the degree of association between variables.

Factor analysis was applied to questionnaire items 1, 2, 5, 8-10, 17-21, 23, 27-30, 40, 51, 53, 64-80, 87, 97-99, 105, and 106 to verify that each of the 14 variables was grouped into the correct second order factor(s) which, for the purpose of this research, are called suprafactors. The factor analysis answered Research Question #5: What variables form together to create suprafactors?.

The structure matrix scores of the variables were examined for the express purpose of rank ordering the variables in each suprafactor. Individual variables with a factor loading between + and - .32 were not considered a significant variable contributing to that specific suprafactor (Tabachnick & Fidell, 1989).

The resulting suprafactors were used as the independent variables in a second regression model. Successful product quality as measured by the sum of conformance to specifications, external failures and product reliability was the dependent variable. The regression analysis was performed to determine which of the suprafactor(s) were significant and to determine the sign associated with the suprafactor.

The general form of the second regression equation is:

$$LSPQ = \beta_o + \beta_1 X_1 + \ . \ . \ . \ + \beta_i X_i + e \qquad (3.4)$$

where

LSPQ = Level of Success of Product Quality, X_1 to X_i are the suprafactor (independent predictors) variables, β's are the unknown parameters and e is the unexplained error associated with this model. Using the least squares estimates as just described, the general form of the regression model becomes

$$LSPQ = b_o + b_1 X_1 + \ . \ . \ . \ + b_i X_i + e \qquad (3.5)$$

The results of this regression analysis addressed Research Question #6: Which suprafactors have a significant effect on production of a quality product in a manufacturing environment?; and #7: What is the relative importance of the suprafactors?

The adjusted R^2 value determined in regression analysis was used to answer Research Question #8: How much of the variance in product quality is explained by these suprafactors?

CHAPTER IV

RESULTS

The purpose of this research was to identify which of the 14 independent variables identified through literature review are significant in producing a quality product in manufacturing, rank order the variables that are significant, and determine the amount of variance explained. Another objective of the research was to identify which of the 14 factors are significant in producing high quality products. The correlation of the 14 variables was calculated, allowing the variables to be grouped according to the strength of their correlation with each other into suprafactors.

Two hypotheses were tested and six major questions addressed. This chapter contains the description of the sample and the statistical analyses of the returned and completed questionnaires developed to address the research questions.

Description of the Sample Population

The population of the study was selected in a two-phase process. Phase I consisted of a random sample of 2,000 members drawn from the American Society for Quality Control's (ASQC) 144,000 membership. The criteria for sample selection consisted of all members who: represented manufacturing facilities (SIC codes between 20-39); classified themselves as mid-level managers; provided a business mailing address; completed all questions related to the study. The job titles of the respondents are presented in Table 6. If a job title was not given, the respondent was placed in the general category of manager.

Table 6

Job Titles of Respondents.

Title	Number of Respondents
Quality Control Manager	251
Quality Assurance Manager	222
Manager	70
Quality Engineer	26
Facility or Plant Manager	26
Production Manager	23
Service Manager	10
Technical Director	9
Purchasing/Supplier Relations Manager	8
Human Resource Manager	6
ISO Project Manager	4
Customer Relation Manager	4
Marketing/Sales Manager	4
Reliability Manager	4
Supervisor	2
Regulatory Compliance Manager	2
Accounting Manager	1
Training Manager	1
Warehouse Manager	1
	674

The questionnaire was sent to all 48 of the contiguous United States and Puerto Rico. Hawaii and Alaska were not included because of the low number of manufacturers who where members of ASQC. Table 7 provides a breakdown of the number of questionnaires returned by state.

Table 7

Number of Questionnaires Returned by State

States	Returned	States	Returned
Alabama	9	Nebraska	5
Arizona	4	Nevada	1
Arkansas	14	New Hampshire	12
California	53	New Jersey	24
Colorado	6	New Mexico	1
Connecticut	6	New York	31
Delaware	1	North Carolina	28
District of Columbia	1	North Dakota	0
Florida	22	Ohio	43
Georgia	23	Oklahoma	10
Idaho	3	Oregon	3
Illinois	44	Pennsylvania	38
Indiana	34	Puerto Rico	5
Iowa	11	Rhode Island	3
Kansas	7	South Carolina	19
Kentucky	21	South Dakota	0
Louisiana	4	Tennessee	21
Maine	4	Texas	37
Maryland	3	Utah	2
Massachusetts	31	Vermont	0
Michigan	60	Virginia	12
Minnesota	14	Washington	7
Mississippi	3	West Virginia	1
Missouri	17	Wisconsin	43
Montana	0	Wyoming	0

The number of questionnaires returned in wave 1 were 357, wave 2 were 258, and wave 3 were 132. The number of responses totaled 747 for a 37.35% response rate. Seventy-three of the questionnaires were returned unanswered for the following reasons: 1) undeliverable (31); 2) respondent chose not to respond (12); 3) the company was not in manufacturing (25); and 4) the respondent was no longer employed with the company (5). Because of the sensitive nature of selected questions, e.g., question 94 (issue of warranty work) and 95 (product liability cost), 123 respondents did not answer the questionnaire in its entirety. This resulted in 551 questionnaires fully completed, a 27.55 % final sample rate. One hundred and thirty-one of the respondents that completed the questionnaire accepted the offer of receiving a summary "copy of the results".

A MANOVA test was conducted to compare the 14 independent variables and the aggregated dependent variable of the "first wave", "second wave" and the "third wave" in order to generalize the findings to the non-respondent sample population. This comparison was tested at the $p < 0.05$ level of significance. The outcome of the MANOVA test determined that there was no significant difference between the respondents in the first, second and third waves, indicating that questionnaires from all three waves were representative of the total sample.

Twenty-seven percent of the companies that responded to the questionnaire were unionized. Plants had an average of 400 workers with an average annual employee turnover rate of 4.3 %. The average number of years companies had a formal quality program was eight years with a standard deviation of 8.6. This figure was skewed to the high side because some companies answering the questionnaire had had a formal quality programs for 20 or more years. The mean dropped to 5.5 years ($\underline{SD}$ = 3.8) when the top five percent of the sample was excluded. Skewness was also reduced from 4.2 to only 1.1. Before running the regression equations, zero order (Pearson) correlations were inspected to determine if multicollinearity was present between the independent variables. Tabachnick and Fidell (1989) suggested that multicollinearity is evident if two variables have correlation of .70 or more. Management participation correlated > .70 with the two variables, communications and training and education (see Appendix C, Table 1). Based on this, the variable management participation was eliminated for consideration as a variable affecting product quality in the total sample.

Reliability of the Questions in the Questionnaire

Reliability of all questions related to both the dependent and independent variables was tested and a Cronbach alpha score determined (see Table 8). The criteria for interpreting the measure ranges from .50 - .59 (poor), .60 - .69 (acceptable), .70 - .79 (good), .80 - .89 (very good), and .90 - .99 (excellent).

The majority of the independent variables had Cronbach alpha scores ranging from good to very good. The dependent variables Cronbach alpha scores ranged from very good to excellent (see Appendix C, Table 8).

Design for Manufacturability (DM) with a score of .53 was the only variable having a score below .60. Question 67 ["Products are easier to manufacture and/or assemble today than three years ago."] and Question 98 ["The company's product quality improvement program has decreased the number of components in your product."], which comprised the DM variable, were left unchanged because they are supported by design for manufacturability theory (Anderson, Schroeder, & Cleveland, 1991).

Findings

Forced stepwise regression was performed with each independent variable being introduced as the first variable into the regression. Results demonstrated that all but one variable (hierarchical organizational structure) were statically significant (see Table 8).

Table 8

The Amount of Variance Explained by Each Variable When First Introduced into the Regression Equation of the Total Sample

Variable Name	T Value
Strategy Emphasizing Product Quality	.0000
Management Participation	.0000
Attitude Toward Risk	.0000
Communications	.0000
Hierarchical Organizational Structure	.1257
Statistical Quality Control	.0000
Management of Materials	.0000
Supplier Relations	.0000
Concurrent Engineering	.0000
Design for Manufacturability	.0000
Experiment of Design	.0000
Employee Empowerment	.0000
Worker Involvement	.0000
Training and Education	.0000

The 13 independent variables were set equal to the dependent variable, Level of Success of Product Quality, and stepwise regression was performed. This analysis was used to test hypothesis #1: "The 14 proposed variables are equally significant among manufacturers."; and to answer Research Question #2: "What is the relative importance of each of the individual variables?" (see Table 9). The variables that were entered into the regression equation are listed in Table 9 in the relative order in which they were entered.

The regression coefficients were calculated and saved. The first number in the equation is the Y-intercept and the βs are the coefficients assigned to each of the variables in the regression. The form of the multiple regression equation became:

$$LSPQ = 1.181811 + .737754\ X_1 + .379924\ X_2 + .443596\ X_3 + .311903\ X_4 + .256120\ X_5 + .320921\ X_6 + .190962\ X_7 + .238125\ X_8$$

where

LSPQ = Level of Success of Product Quality, and

X_1 = Communications

X_2 = Design for Manufacturability

X_3 = Strategy Emphasizing Product Quality

X_4 = Materials Management

X_5 = Concurrent Engineering

X_6 = Worker Empowerment

X_7 = Statistical Quality Control

X_8 = Attitude Toward Risk

were the independent (predictor) variables.

Table 9

Regression Results for Variables Regressed on Level of Success of Product Quality for the Total Sample

Variable Name	DF	β Value	T Value
Communication	1	.737754	.0000
Design for Manufacturability	1	.379924	.0001
Strategy Emphasizing Product Quality	1	.443596	.0002
Management of Materials	1	.311903	.0031
Concurrent Engineering	1	.256120	.0101
Worker Empowerment	1	.320921	.0128
Statistical Process Control	1	.190962	.0214
Attitude Towards Risk	1	.238125	.0358
(Constant)		1.181811	.0394

Question #3: "How much variation in product quality is explained by the statistically significant individual variables?" was then addressed. The adjusted R^2 was .51182, indicating that the eight significant variables account for approximately half of the variance in product quality in manufacturing.

Figure 3, Appendix D, is a standardized residual histogram of a normal distribution overlaid with the sample distribution. The distribution was determined to be normal with a mean of -.0211 (S.D. = 1.0042). The sample distribution satisfied the normality requirement for the regression model. The skewness of the data was tested at a statistical significance level of $p = 0.05$ and was non-significant.

A normal probability plot (see Appendix D, Figure 4) was employed to examine the linearity of the relationship between variables. This plot suggests that the regression model was a good predictor of product quality; therefore, the regression equation fit the data.

A scatterplot (see Appendix D, Figure 5) of the standardized residuals was plotted to determine if the residuals were randomly distributed. There was no detectable pattern and an assumption of random distribution was accepted.

Selection of High Quality Manufacturer's Sample

A Baldrige Award score was calculated for 612 completed questionnaires. For the total sample Baldrige scores ranged from 160 to 990 with the top 40% ranging from 668 to 990. This sample was used in the calculation to answer Hypothesis #2 and Research Questions 5-8. A sample size of 245 (40% of the sample) was chosen in order to achieve the goal of reliability of results. Tabachnick and Fidell (1989) suggest, when using multiple regression, that the sample size have 20 times more cases than independent variables. Comrey (1973) recommends a sample size between 200 to 300 cases when using factor analysis for good, reliable results.

Before running the regression equations, zero order (Pearson) correlations were inspected to determine if multicollinearity was present between the independent variables. No significant zero order correlations were detected (see Appendix C, Table 2).

Forced stepwise regression was performed with each independent variable as the first variable introduced into the regression. The results were that all but one variable (hierarchical organizational structure) was statistically significant at the $p = .05$ level when examined singularly (see Table 10)

Table 10

The Amount of Variance Explained by Each Variable When First Introducted into the Regression Equation of the Subsample of Manufacturers of High Quality Products

Variable Name	T Value
Strategy Emphasizing Product Quality	.0000
Management Participation	.0000
Attitude Toward Risk	.0001
Communications	.0000
Hierarchical Organizational Structure	.0841
Statistical Quality Control	.0180
Materials Management	.0000
Supplier Relations	.0000
Concurrent Engineering	.0399
Design for Manufacturability	.0005
Experiment of Design	.0394
Employee Empowerment	.0002
Worker Involvement	.0127
Training and Education	.0000

The 14 independent variables were set equal to the dependent variable, Level of Success of Product Quality, and stepwise regression was performed on the subsample. This analysis was used to test hypothesis #2: The 14 proposed variables are equally significant among manufacturers of high quality products (see Table 11). The variables that were found statistically significant are listed in order of importance in Table 11. Significance level was established at $p = .10$.

Table 11

Regression Results for Variables Regressed on Level of Success of Product Quality of Manufacturers of High Quality Products

Variable Name	DF	B Value	T Value
Communication	1	.888037	.0013
Design for Manufacturability	1	.206302	.0231
Management of Materials	1	.644645	.0433
Strategy Emphasizing Product Quality	1	.443596	.0505
Training and Education	1	.433997	.0752
(Constant)		6.065277	.0000

The regression coefficients were calculated and saved. The first number in the equation is the Y-intercept and the βs are the coefficients assigned to each of the variables in the regression. The form of the multiple regression equation for production of high quality product(s) in a manufacturing environment becomes:

$$LSPQ = 6.065277 + .888037\ X_1 + .206302\ X_2 + .644654\ X_3 + .433997\ X_4 + .433997\ X_5$$

where

LSPQ = Level of Success of Product Quality, and

X_1 = Communications

X_2 = Design for Manufacturability

X_3 = Materials Management

X_4 = Strategy Emphasizing Product Quality

X_5 = Training and Education

are the independent (predictor) variables. The amount of variance in quality explained by the significant variables in producers of high quality products is represented by the adjusted R^2 which was determined to be .19488.

Figure 6, Appendix D, is a standardized residual histogram of a normal distribution overlaid with the sample distribution. The distribution was determined to be normal with a means of -.0473 and a standard deviation of 1.0261. The sample distribution satisfied the normality requirement for the regression model. The skewness of the data was tested at a statistical significance level of $p = 0.05$ and was non-significant.

A normal probability plot (see Appendix D, Figure 7) was employed to examine the linearity of the relationship between variables. This plot suggests that the regression model is a good predictor of product quality; therefore, the regression equation fits the data.

A scatterplot (see Appendix D, Figure 8) of the standardized residuals was plotted to determine if the residuals were randomly distributed. There was no detectable pattern and an assumption of random distribution was accepted.

Factor Analysis

It has been proposed that the identified variables can be grouped together (organized) into common factors. Tabachnick and Fidell (1989) suggested that factor analysis applied to a single set of variables allows the researcher to discover which variables in the set form coherent subsets that are relatively independent of one another. The specific goals of factor analysis are to summarize patterns of correlations among observed variables and to reduce a large number of observed variables to a smaller number of factors.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used to evaluate the fit of the model used in this study. Tabachnick and Fidell (1989) suggests that a KMO score between .80 and .89 is considered "very good".

The resulting measure of sampling adequacy for the sample was .81384.

Tabachnick and Fidell (1989) suggests that factor loading scores in excess of .71 are considered excellent, .63 very good, .55 good, .45 fair, and .32 poor. Variables were considered loaded on a factor if the factor loading score was .32 or higher.

Factor analysis was performed on the 14 variables to determine the minimum number of factors that could be adequately accounted for by observed correlations. In this analysis eigenvalues are used to determine factors. The resulting number of eigenvalues greater than one resulted in four factors extracted. Because one variable, hierarchical organizational structure, did not have a factor score of .32 or greater on any of the four extracted factors, factor analysis was repeated forcing a fifth factor into the solution with an eigenvalue lower than one (eigenvalue of .93761). Varimax rotation converged in 13 iterations and factor scores from each variable were saved to be used for calculations in the regression model. The resulting factor loadings are displayed in Table 12.

Table 12

Aggregation of Variables into Suprafactors and Factor Loading

Factor	Variables	1	2	3	4	5
1	Communication	.63843	.47156	-.02671	-.09572	.04916
	Worker Empowerment	.73393	.13053	-.05988	.11627	.16903
	Attitude Toward Risk	.66554	.32496	.00909	.13163	.12473
	Worker Involvement	.68970	-.14014	.23354	.16604	-.12656
	Training and Education	.33731	.46731	.55217	-.00027	-.09741
	Management Participation	.49061	.56723	.30332	-.06681	-.01784
2	Communication	.63843	.47156	-.02671	-.09572	.04916
	Attitude Toward Risk	.66554	.32496	.00909	.13163	.12473
	Management of Materials	.13364	.58874	-.04027	.24942	-.13241
	Supplier Relationship	.03508	.67757	.09951	.38301	.18870
	Training and Education	.33731	.46731	.55217	-.00027	-.09741
	Management Participation	.49061	.56723	.30332	-.06681	-.01784
	Strategy Emphasizing Product Quality	.12990	.68032	.28375	-.01969	.11934
3	Experiment of Design	-.06802	.08488	.68962	.42260	.17395
	Training and Education	.33731	.46731	.55217	-.00027	-.09741
	Statistical Quality Control	.04762	.11293	.84921	.03263	.04384
4	Concurrent Engineering	.01386	.30912	.09579	.77205	.02533
	Experiment of Design	-.06802	.08488	.68962	.42260	.17395
	Design for Manufacturability	.26804	-.01612	.11889	.78044	-.13139
	Supplier Relationship	.03508	.67757	.09951	.38301	.18870
5	Hierarchical Organizational Structure	.13686	.03967	.10083	-.06196	.92489

Suprafactor Names

Factor 1 = Personnel Environment
Factor 2 = Strategic Planning
Factor 3 = Operational Control and Process Improvement
Factor 4 = Product Design and Development
Factor 5 = Hierarchical Organizational Structure

Based on the computed factor loadings, Factor 1 represents personnel environment, Factor 2 represents strategic planning, Factor 3 represents operational control and process improvement, Factor 4 represents product design and development, and Factor 5 represents hierarchical organizational structure. For the purpose of this research each factor was designated a suprafactor. This answers Research Question 5: "Which variables group together to create suprafactors?" (see Figure 1).

The five suprafactors were set equal to the dependent variable, Level of Success of Product Quality, and stepwise regression was performed. The four suprafactors that were found statistically significant are listed in the order they entered the regression equation (see Table 13). Significance levels was established as $p < .10$. Results were used to answer Research Questions #6: "Which suprafactors have a significant effect on production of high quality product(s) in a manufacturing environment?"; and Research Question #7 "What is the relative importance of the suprafactors?" (see Table 13).

Suprafactor	Variable
Personnel Environment	Communication Worker Empowerment Attitude Toward Risk Worker Involvement Training and Education Management Participation
Strategic Planning	Communication Attitude Toward Risk Management of Materials Supplier Relationship Training and Education Management Participation Strategy Emphasizing Product Quality
Operational Control and Process Improvement	Experiment of Design Training and Education Statistical Quality Control
Product Design and Development	Concurrent Engineering Experiment of Design Design for Manufacturability Supplier Relationship
Hierarchical Organizational Structure	Hierarchical Organizational Structure

Figure 1. Suprafactors and their associated variable(s).

Table 13

Regression Results for Suprafactors Regressed on Level of Success of Product Quality

Variable Name	DF	B Value	T Value
Personnel Environment	1	.747856	.0000
Strategic Planning	1	.634105	.0000
Operational Control and Process Improvement	1	.266490	.0647
Product Design and Development	1	.257507	.0742
(Constant)		16.729728	.0000

The factor loading coefficients were calculated and saved. The first number in the equation is the Y-intercept and the βs are the coefficients assigned to each of the variables in the regression. The form of the regression equation became:

$$LSPQ = 16.729728 + .747856\ X_2 + .634105\ X_1 + .266490\ X_3 + .341835\ X_4$$

where

LSPQ = Level of Success of Product Quality

X_2 = Strategic Planning

X_1 = Personnel Environment

X_3 = Operational Control and Process Improvement

X_4 = Product/Process Design and Development.

X_1 - X_4 are the independent (predictor) suprafactors.

Research Question #8: "How much variation in product quality is explained by these suprafactors?" was then addressed. The adjusted R^2 was .16804, and indicated that the four significant suprafactors accounted for approximately one-sixth of the variance in product quality in manufacturing.

CHAPTER V

DISCUSSION AND IMPLICATIONS

The study results (Phase I, II, III), sample and study instrument will be discussed in this chapter, and the findings will be related to manufacturing literature. A model representing the study variables and suprafactors identified in the environment of manufacturers of high quality products will be presented. Limitations of the study, and implications for future research will also be discussed.

Study Results

Phase I: Total Sample Results

This section's discussion is limited to Hypotheses 1 and 2 and Research Questions #2 and #3. Hypothesis 1 is "The 14 proposed variables are equally significant among manufacturers." Research Question #2 is "What is the relative importance of each of the individual variables?" Research Question #3 is "How much variation in product quality is explained by these variables?"

Strategy Emphasizing Product Quality

To determine whether a company had a strategy emphasizing product quality, managers were asked: "Is product quality integrated into the company's strategic plan?"; "Is this strategic plan projected into the future?" Skinner (1969) and Wheelwright and Hayes (1985) had suggested that the goal of attaining a quality product was to integrate product quality into the overall business strategy. This study found that a company's strategic policy of emphasizing product quality was statistically significant in the total sample. This finding supports prior research by Juran (1991), Anderson et al., (1991), and Porter (1985).

Management Participation

Management participation was eliminated as a variable in the total sample because of multicollenarity with two variables, communication and training and education. For this variable, managers were asked whether "Managers are instructors in quality training programs." Responses to this question demonstrated emphasis on the educator aspect of management and resulted in multicollinearity between the variables: 1) communication and 2) training and education.

The fact that management participation was eliminated with total sample analysis does not negate the variable as an important variable in the manufacture of a quality product. One of the variables, communication, was significant and may be masking the contribution of management participation. Management's participation in providing workers with the proper tools and knowledge (training and education) is the sixth point of Deming's 14 Points for continuous product quality improvement (Evans & Lindsay, 1995). This result, in fact, appears to downplay the importance of management participation and contrasts with the views of Evans and Lindsey. Evans and Lindsay (1995) suggested managers must take the responsibility for providing the training and education.

Attitude Toward Risk

Questions used to measure "attitude toward risk" in this study were: Are employees encouraged to make independent decisions?; Is there trust between managers and employees?" Total sample results found attitude toward risk to be statistically significant. These results are congruent with the views of Benson (1990), who indicated the need for positive relationships between workers' trust of management and their willingness to take risks. Deming (1981-1982) believed in order for workers to participate in the quality improvement effort, fear had to be eliminated from the workplace. No other studies examining attitude toward risk and its effect on product quality were found. This present study, consequently, is the first empirical study correlating attitude toward risk and its impact on product quality.

Communication

Communication issues addressed in this research were measured using questions: Are the company's mission, strategic plan, goals and objectives shared with everyone at all levels of the organization?; Are workers allowed to air problems concerning issues in the plant?; Do employees know that their suggestions are being received up the ladder and acted upon? Results with the total sample of managers found communication was statistically significant. This finding confirmed views expressed by Clark, (1989), Wriston (1990) and Kinnie et al. (1992). A bi-directional communication environment provides a means for management's messages of encouragement and goals of the company to be received clearly by the line workers (Clark, 1989). Wriston (1990) suggested that bi-directional communication creates and supports a corporate environment that is safe for employees to try new ideas and manufacturing methods without fear of losing their jobs. A work environment demonstrating bi-directional communication will facilitate an atmosphere of mutual support and trust between management and workers (Kinnie et al., 1992).

Hierarchical Organizational Structure

The questions addressing hierarchical organizational structure were: How many levels of management were between line workers and the highest level of management at your location?; Five years ago, how many levels of management were between line workers and the highest level of management at your location? For the total sample, companies had a present mean of 3.08 levels of management (SD = 1.31) and the mean five years ago was 3.345 (SD = 1.43). These findings support Drucker's (1988a) views that the trend for organization management structures is to become flatter and Schonberger's (1986) belief that there need be no more than four levels of management above line workers at a plant.

Hierarchical organizational structure was non-significant in the total sample. The outcome disagrees with Bush's (1992) finding that organizational downsizing has had a positive effect on product quality when companies had active employee participation programs. Bush looked at both the effects of employee participation programs and downsizing on product quality. There may have been confounding effects between the two variables because Bush did not identify which one of the variables was the main effect creating the change in product quality. No other empirical studies were found that addressed the effect of the number of management levels on product quality.

Statistical Quality Control

To determine whether a company was using statistical quality control, managers were asked: "Management promotes the use of quality control tools (such as X-bar charts, process control charts, etc.) in manufacturing processes."; "The manufacturing processes are controlled by statistical process controls." Statistical quality control was statistically significant in determining product quality for the total sample. This finding provides support for Deming's (1981-1982) and Drucker's (1988b) assertions that SQC is a significant aid in controlling product quality in manufacturing.

Management of Materials

Management of materials was addressed in this research using questions: "Suppliers meet most of the company's quality requirements."; "Primary suppliers have a quality assurance plan or manual with a written set of procedures."; "Materials are purchased from suppliers whose quality has been formally certified." Management of Materials was statistically significant in product quality in manufacturing for the total sample. This finding was congruent with Crosby (Lascelles & Dale, 1989) and Ishikawa (1985). Both suggested that at least 50% to 70% of a company's quality nonconformance problems are caused by defective purchased material. This study also supports Watts, Kee, and Hahn's (1992) finding that management of materials plays an increased role in the success of today's companies in terms of product quality and corporate competitiveness.

Supplier Relations

The questions used to address supplier relations were: "Suppliers are involved in the product quality planning process."; and "There are regularly scheduled meetings with primary suppliers." Supplier relations was statistically non-significant in determining product quality in manufacturing for the total sample. Giunipero and Law (1990) found that supplier performance and capabilities are important in producing a quality product. This assertion were not supported by the findings.

A rationale for supplier relations being non-significant can be partially explained by the correlation between the variables already in the equation (see Appendix C, Table 5). In other words, supplier relations' contribution to the explained variance was already explained by a combination of previously entered variables in the regression equation.

Concurrent Engineering

Questions that addressed the variable, concurrent engineering, are: "The company's quality improvement program decreased the time it takes to design new product."; "Concurrent engineering methods are used to design new products." Concurrent engineering was statistically significant for producing a quality product for the total sample. The findings support Clark's (1989) and Drucker's (1990) that a quality improvement program can decrease the design process time for new product.

Design for Manufacturability

Questions addressed in design for manufacturability were: "The company's quality improvement program decreased the number of components in your products."; "Products are easier to manufacture and/or assemble today than three years ago." Design for manufacturability was statistically significant for the total sample. This finding is congruent with Whitney's (1988) assertion that reducing the number of product components results in increased product quality. Anderson et al. (1991) suggested that simplifying the product design will increase product quality.

Experiment of Design

Managers were asked: "Experiment of design techniques, i.e., Taguchi, are used to improve product design." to address EOD. Experiment of design was found to be non-significant for product quality in manufacturing for the total sample. The finding does not support Ross (1988) and Byren and Taguchi (1987), both of whom suggested that the use of EOD enhances product quality.

This suggests, that part of the variance explained by EOD was already explained by variable(s) already in the regression equation. Perhaps the questions used to determine the score for EOD did not adequately explore the relationship between EOD and product quality in manufacturing, or there were not enough users of EOD represented in the sample to adequately test the variable. This latter condition may be operating because most manufacturers in the sample did not use this advanced technique for solving product problems (see Appendix C, Table 4).

Worker Empowerment

Questions addressing worker empowerment were: "Employees inspect their work for defects."; "Employees have the authority to halt the production process."; Customer service employees are empowered to resolve customers' complaints quickly." Worker empowerment was statistically significant in product quality in manufacturing for the total sample.

This finding supports Bennis (1990a, 1990b, 1991), Maskell (1991) and Feigerbaum (1992) that an empowered work force has a sense that they are at the center of things and are contributing to the organization's success. Dean and Evans (1994) also suggested that empowered employees make decisions themselves and are responsible for their outcomes.

Worker Involvement

Questions concerning worker involvement were: "The product quality policy emphasizes the need for employee involvement."; "Employees are involved in the product quality planning process."; "The product quality program has led to an increased number of workers' suggestions to improve product and/or process quality."; "What percentage of the workers' quality improvement suggestions are implemented?" Worker involvement was not statistically significant for manufacturing a quality product for the total sample. Dean and Evens (1994) and Schonberger (1986), suggested that worker involvement is necessary if a company is to achieve world class product quality. These assertions were not supported in the present study with total sample results.

A rationale for worker involvement being non-significant can be partially explained by the correlation between the variables already in the equation (see Appendix C, Table 5). In other words, worker involvement's contribution to the explained variance was already explained by a combination of previously entered variables in the regression equation.

Training and Education

Questions used to address training and education were: "Management has received adequate training on how to use quality control tools."; Human resource programs that integrate product quality goals with employee training are in place."; "There is a quality improvement training program for employees"; Employees are trained to do more than one job." Training and education was non-significant for the total sample. Senge (1990b) suggested that continuous training and improvements are the cornerstones of a learning organization. Juran (1991) stated that extensive training on the use of quality tools is required for companies to improve product quality. These assertions were not supported by the present study.

A rational for training and education being non-significant can be partially explained by the correlation between the variables already in the equation (see Appendix C, Table 5). In other words, training and education's contribution to the explained variance was already explained by a combination of previously entered variables in the regression equation.

Phase II: Baldrige Award Selected Sample

This section's discussion is limited to Hypotheses 2. Hypothesis #2 tested whether the 14 variables were significant in producing a high quality product in manufacturing. The Baldrige criteria were used in the selection process of the subsample. The focus of the Baldrige criteria is on process issues related to product quality and is based on information and analysis, human resource development and management, management of process quality, quality and operations results, and customer focus and satisfaction. The use of the Baldrige selection process increased the robustness of the research findings because product quality decisions were not made on the sole criterion of quality of the product. Other issues should be considered in the decision-making process regarding quality, i.e., process capability, information flow, labor-management relations, level and type of competition, etc.

Review of the literature found no research addressing quality using the Baldrige award criteria to establish group membership. Therefore, this was the first empirical research to determine the level of variance explained by product quality using the Baldrige award criteria as sample selection criteria.

Five variables, communication, training and education, design for manufacturability, management of materials, and strategy emphasizing product quality were statistically significant in producing a high quality product.

Four of the statistically significant variables, communication, design for manufacturability, management of materials, and strategy emphasizing product quality, were discussed in Phase I. The fifth variable, training and education, is now addressed. Training and education was non-significant for the total sample but statistically significant among producers of high quality products. The implication is that high quality producers emphasized training and education and supported efforts to improve their workers' job skills. Literature related to quality issues strongly advocates training and education in quality for all members of an organization. The finding, that extensive training is one of the keys to quality products, supported Juran (1991), Webber (1993), and Kinnie et al. (1992). In addition, Clark (1989) indicated that knowledgeable workers are a company's only real capital corporate asset, and that they provide a sustainable competitive advantage in different types of manufacturing environments.

The subsample results, selected by the Baldrige criteria, found the following variables were statistically non-significant: management participation, attitude toward risk, statistical quality control, supplier relations, concurrent engineering, experiment of design, worker empowerment, worker involvement, and hierarchical organizational structure. The scoring criteria of the Baldrige Award may have shifted emphasis on some aspects of manufacturing a quality product. This created a subsample in which the variables of communication, training and education, design for manufacturability, management of materials, strategy emphasizing product quality, and training and education, are highly valued attributes.

The Baldrige criteria are: leadership, information and analysis, strategic quality planning, human resource development and management, management of process quality, quality and operations results, and customer focus and satisfaction. When these are considered along with specific product quality variables, a decision-making process focusing on determining a global optimal product quality solution is revealed. This suggests that when Baldrige criteria and specific product quality variables are considered jointly, manufacturer's product quality priorities are affected.

In the total sample calculation of variance explained by the 14 variables, only product quality was taken into consideration without regard to any other issues. In the second calculation, the Baldrige Award criteria were used as a selection variable. The effect was that the amount of variance explained by the 14 variables decreased from .51182 to .19488. The reduction in the amount of explained variance may result from criteria used to select the subsample. With this subsample analysis, the Baldrige criteria were essentially added to the criteria used to define the dependent variable, product quality.

Phase III: Factor Analysis of the Data from Manufacturers of High Quality Products

Five main factors or suprafactors were delineated by factor analysis. These were personnel environment, strategic planning, operational control and process improvement, product design and development, and hierarchical organizational structure. To facilitate discussion, a model was developed to show the interaction of the five suprafactors and integration of the original 14 variables identified in the literature. It is difficult, if not impossible, to discuss one suprafactor without bringing in the shared components of other suprafactors. This has led to the development of the Quality Product Interlinking Chain Model, composed of four interlinking rings (see Figure 2). This model was developed to explain the relationships between and among the suprafactors, and the variables that are their components.

The suprafactor, Strategic Planning, is the hub or center of the Quality Product Interlinking Chain Model. This is where the strategy planning process of using high product quality to gain a competitive advantage begins. The variables associated with the Strategic Planning suprafactor are communication, attitude toward risk, management of materials, supplier relationship, training and education, management participation, and strategy emphasizing product quality. The other three suprafactors, Personnel

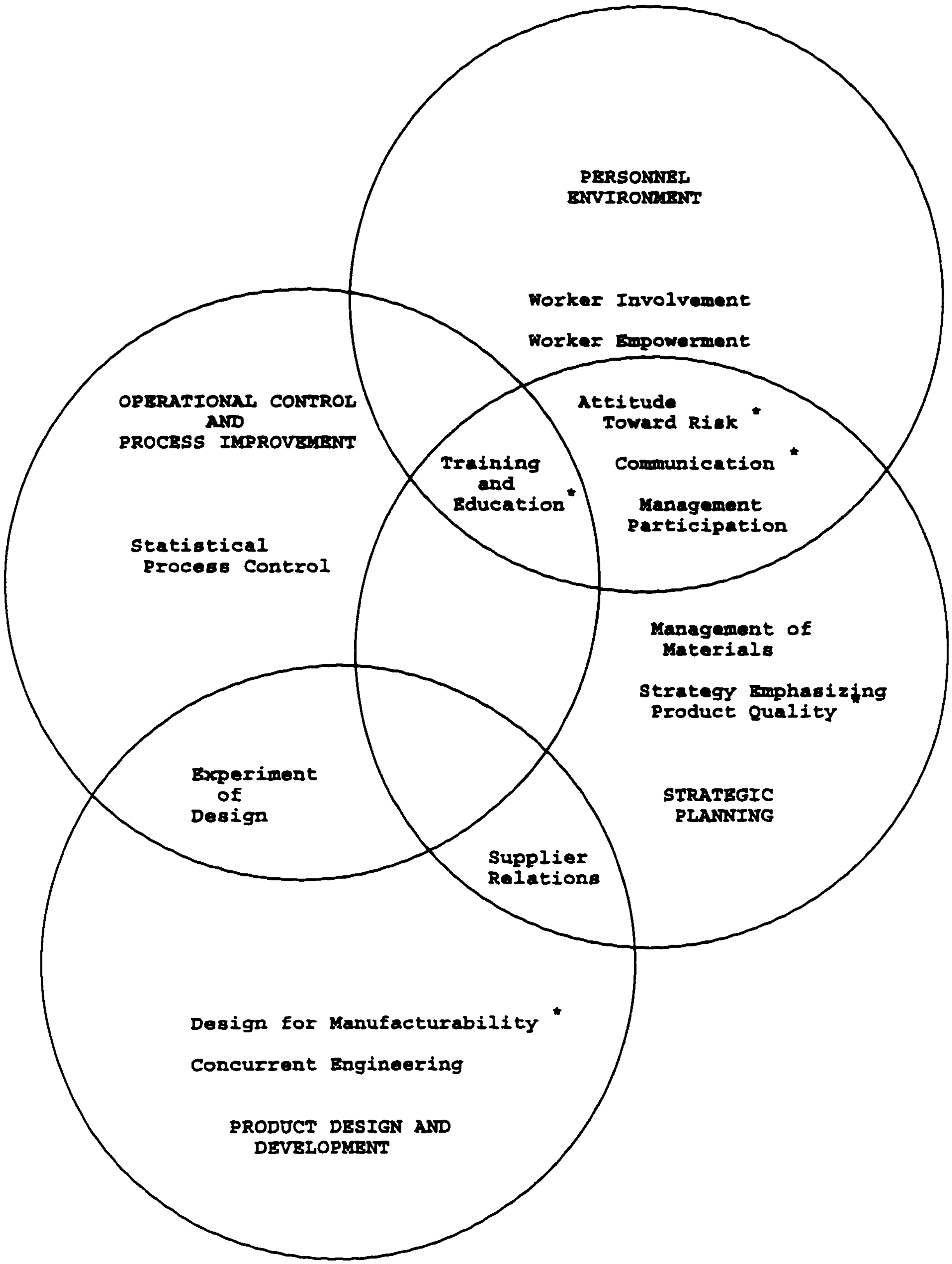

Figure 2.

The Quality Product Interlinking Chain Model.

* Variables are statistically significant.

Environment, Operational Control and Improvement, and Product/Process Design and Development, are directly connected to the central suprafactor, Strategic Planning, through shared common variables. There is bi-directional information flowing from these suprafactors to and from of the central suprafactor which acts as a focal point and clearinghouse for all training and education and communication activity. This suprafactor, Strategic Planning, is so named because it is the focal point of the necessary information support required for developing a high quality product strategic plan.

The second statistically significant suprafactor is Personnel Environment. The Personnel Environment suprafactor shares four variables, communication, attitude toward risk, management participation, training and education, with the Strategic Planning suprafactor. In addition to these four variables, worker empowerment and worker involvement variables are components of the Personnel Environment suprafactor. This suprafactor is so named because of the humanistic issues involved.

Meaningful bi-directional communication and the free flow of information can only take place between workers and management if fear has been driven from the workplace (Deming's eighth point) (Evans & Lindsay, 1995). Workers are involved and empowered in this climate of trust.

Training and education support effective worker involvement and interaction between management and worker .

The third suprafactor, Operational Control and Process Improvements, is made up of three variables, statistical quality control, EOD, and training and education. As the name implies, this suprafactor is concerned with process control of the manufacturing process.

Operational Control and Process Improvement, is linked with Strategic Planning and Personnel Environment through training and education. Operational Control and Process Improvement suprafactor is one in which workers are given the tools to detect line problems and to correct them. For the workers to be most effective, they need training to use these tools. The use of SQC methods will allow workers to determine if a process is under control and, if not, will help indicate problem areas of quality in the product or process. Experiment of design can be used to improve the robustness of the product or process but the use of this advanced technique requires additional worker education.

There are situations where product quality problems on the line can be traced back to basic design flaws in a product. The product design problems link back to the Product Design and Development suprafactor.

Product Design and Development, the fourth suprafactor, is comprised of four variables; design for manufacturability, concurrent engineering, EOD, and supplier relations. Product Design and Development is the creative area in the development of new product and redesigning of existing products. This requires cooperation and participation of all the functional areas of the firm in the product design activity and provides a method for affected suppliers to contribute their unique knowledge to the creative process (Anderson et al., 1991). The end result should be a new or existing product with fewer parts and simpler assembly (Coughlan & Wood 1992).

Product Design and Development is linked by the variable, supplier relations, to Strategic Planning which is the beginning. The linkages are made from one suprafactor to another until the product quality circuit is complete. The use of linkages in the Quality Product Interlinking Model reveals the connections between cause and effect of the total product quality picture.

The following is an example of the interconnectivity of the :

> A manager is facilitating an SQC training class with line employees. As employees grasp the concepts and learn how SQC is applied to their particular situation, they share some of their problems on the line and managers demonstrate how SQC can support employees in determining the problem and its elimination. From this encounter of workers and managers, a bi-directional dialogue

is initiated, resulting in managers learning of line problems, workers getting involved in problem-solving and being empowered to correct problems. If the source of the problem is component related, the vendor would be called in to participate in the problem-solving process. If the problem proves to be complex, more advanced methods, such as EOD, may be used to find a solution to the problem. Outcomes from this one imaginary management/worker encounter take place on two levels: 1) At the production line where the problems were observed, the encounter may uncovered a major problem that changes the entire production process. 2) The second outcome from such an encounter is a demonstration of commitment to product quality, expressed by actions and deeds, which are aligned with and supportive of the company's strategy. This corporate behavior adds credence to management actions and nurtures an environment where mutual respect and trust grow between workers and managers.

Use of the Quality Product Interlinking Chain Model will assist managers in understanding that change in one aspect of product quality in a manufacturing environment affects everyone and everything in that environment. The Quality Product Interlinking Chain Model may explain why targeting a particular department or product to solve a quality problem is not effective unless the solution can be linked throughout the Quality Product Interlinking Chain Model's interlinking rings.

Hierarchical Management Structure suprafactor is unique because it has only one highly associated variable. In this model, hierarchical management structure appears to have limited direct impact on the quality product process. Because of the lack of available research information about how elimination of middle management levels from the corporate structure impact product quality, one can only speculate how this variable is affecting product quality.

Limitation of the Present Research

One limitation is that the sample population was drawn from mid-level managers who are members of ASQC. This limits the generalizability of the results to companies with managers who are members of ASQC in the manufacturing sector. This issue was addressed by using a large randomly selected sample spanning the 48 contiguous states in order to make it as representative as possible of all types of manufacturers in the U.S.

Because of the financially sensitive nature of the questions relating to the dependent variable, External Failures Lead to Warranty and Liability Claims, some respondents would not or could not give a response. This may have biased the response in the dependent variable.

The is the first study that has used this questionnaire. The reliability of the questionnaire has not been established. Additional research using this questionnaire is required to establish reliability. Cronbach Alpha scores for supplier relations (.65), concurrent engineering (.65), design for manufacturability (.53), and worker empowerment (.66) could be increased by adding questions related to each variable.

There was a multicollinearity problem with management participation in the total sample. The questions related to management participation may require rewording to address the problem.

The response rate to the questionnaire was 37.5%. Although respectable in survey research, results may have varied had an increase in response rate approximated the 2,000 sample size.

Multiple regression was used to determine the amount of explained variance in product quality by the 14 variables which was .51182. This indicates that over half of the variation in product quality is explained by these variables when only product quality is considered. The possibility exists that other critical variables were not studied in this research.

When the Baldrige Award was used to determine the companies that were producers of high quality product(s), the 14 variables only explained .19488 of the variance in product quality. Approximately 80% of the variance remained unexplained. It is possible that variables directly or indirectly related to manufacturing high quality product are affecting quality but are not considered in this research such as, product's aesthetics, fill rate, etc.

Garvin (1987) suggested that product quality could be measured on eight dimensions (characteristics). These were: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. The level of explained product quality could be increased if some of these variables, such as customers' perceived quality of a particular product(s) or product groups, product serviceability after the sale, had been included. These variables are not easily measured and tend not to lend themselves to survey research. Measuring quality on all dimensions would require researchers to survey a representative sample of the customer base of firms in a study and to conduct Baldrige-type plant quality audits.

Implications for Future Research

The next stage of research logically addresses a replication of the present study to determine whether results can be reproduced with another group of middle managers, line workers or with different levels of management.

Additional areas of interest that will be investigated as a results of this research are "Which 14 variables have the greatest impact on legal and warranty issues?", "Do ISO 9000 registered companies produce higher quality products than non-registered companies?", "Does the presence of unions in a company affect product quality?", "Which of the 14 variables are critical in a JIT environment?", "Which of the 14 variables are critical in a TQM environment?", "Do makers of high quality products reap greater financial rewards than the other producers?", and "What is the effect of the 14 variables on product quality while blocking by type of industry."

The present research did not support hierarchical management structure being a statistically significant variable affecting product quality. Future research can be directed toward determining if such a linkage exists.

A major focus of future research will be the expansion of the model by including financial and productivity issues as dependent variables. With this new information, it will be interesting to watch what happens to the linkages as they are weakened, strengthened or new ones created. This line of investigation should lead to a more robust Quality Product Interlinking Chain Model and a better understanding of the product quality interlocking rings.

Another major focus of future research will focus on the manufacturing company's product quality developmental changes as they evolve into high quality producers. This could be presented using the four-stage model developed by Wheelright and Hayes (1985). The purpose of such research would be to develop a "road map" for managers to determine where their company was on the highway to higher product quality and where to concentrate limited resources in order to get to the next higher stage in the model.

Summary

A survey using a randomized sample of 2,000 mid-level managers from the 48 contiguous states in the U. S. and Puerto Rico, who were members of American Society for Quality Control, was conducted to determine the essential elements of manufacturing a quality product. The survey instrument designed to elicit evaluation of the manufacturing environment at the plant level was developed for the study.

The 14 variables identified in the literature and tested for significance in developing a quality product will be discussed in relation to Phase I, the total sample, and Phase II, the Baldrige Award sample, analysis and followed with Phase III, a discussion of the suprafactors.

Phase I used 551 responses to the total survey. Phase II and III of the analysis was conducted with a subsample of 265 respondents, 40 % of the total sample. The subsample was chosen by using Section I of the questionnaire relating to Baldrige Award criteria. Respondents to the criteria receiving a score of 668 or more out of a possible 1,000 points were considered manufacturers of high quality products.

The total sample and the subsample were found to have normal distributions (see Appendix D, Figures 3 and 6), residuals were plotted for both samples to determine goodness of fit of the line of regression (see Appendix D, Figures 4 and 7), and a scatterplot of both samples was used to determine if the residuals were randomized (see Appendix D, Figures 5 and 8). The distributions were determined to be normal and there were not any detectable patterns of the residuals in the scatterplots. This indicated that assumptions of normal distribution, linearity, and lack of skewness had been met with both the total sample and the subsample. Analysis using multiple regression could then be used with confidence that assumptions for the use of statistical procedures had been met.

The 14 variables identified through review of the manufacturing literature as essential for the development of a quality product are strategy emphasizing product quality, management participation, attitude toward risk, communications, hierarchical organizational structure, statistical quality control, management of materials, supplier relations, concurrent engineering, design for manufacturability, experiment of design, employee empowerment, worker involvement, training, and education.

For Phase I, one hypothesis and two research questions were addressed: Hypothesis #1: "The 14 proposed variables are equally significant among manufacturers."; Research Question #2: "What is the relative importance of each of the individual variables?"; Research Question #3: "How much variation in product quality is explained by these variables?".

In Phase I, analysis with the total sample addressed whether the 14 variables were significant in the production of a quality product. Questionnaire data from the total sample were analyzed using multiple regression procedures established at $p < .05$. Stepwise regression was done to determine which of the 14 variables were statistically significant, the relative rank order of significant variables, and the amount of variance explained by the significant variables.

One variable, management participation, was eliminated from analysis because of multicollinearity with two other variables (communication, and training and education). When the remaining thirteen variables were regressed as a group, eight were found to be statistically significant in providing a quality product in manufacturing. Using stepwise regression procedures, the eight variables in the order of most to least importance were communications, design for manufacturability, strategy emphasizing product quality, management of materials, concurrent engineering, worker empowerment, statistical quality control, and attitude toward risk. The amount of variance explained by these variables was .51182.

The elimination of three of the variables, supplier relations, training and education, and worker involvement, as non-significant can be partially explained by the correlation between the variables already in the equation (see Appendix C, Table 5). In other words, the non-significant variables' contribution to the explained variance was already interpreted by a combination of previously entered variables in the regression equation. This is the manufacturing equivalent of tolerance stack-up of machined parts. Experiment of design was used by so few of the respondents in the total sample that it was not found significant (see Appendix C, Table 4). Hierarchical organizational structure was non-significant and appears to not influence product quality.

For Phase II, Hypothesis 2 is addressed: The 14 proposed variables are equally significant among manufacturers of high quality products. The hypothesis was similar to those in Phase I, but analyzed with the subsample of 245 managers from high quality product manufacturing environment. Statistically significant level was established at $p < .10$.

In Phase II, a subsample of manufacturers of high quality products was selected based on the Baldrige Award criteria, analysis addressed whether the 14 variables were statistically significant in manufacturing of a high quality product. Five variables were statistically significant and their rank order of importance are: communication, design for manufacturability, management of materials, strategy emphasizing product quality, and training and education. Amount of variance explained was .19488.

The results of Phase I and Phase II are displayed in Table 14. The 14 variables for each analysis are displayed with the variables that were determined to be statistically significant in rank order of importance along with the variables that were found to be non-significant.

For Phase III, four research questions were addressed: Research Question #5: "Which variables group together to create suprafactors?"; Research Question #6: "Which suprafactors have a significant effect on production of high quality product(s) in a manufacturing environment?"; Research Question #7: "What is the relative importance of the suprafactors?"; Research Question #8: "How much variation in product quality is explained by these suprafactors?".

Table 14

Significant Variables in the Total Sample and the High Quality Product Sample

	Quality Products	High Quality Products
Significant	Communication Design for Manufacturability Strategy Emphasizing Product Quality Management of Materials Concurrent Engineering Worker Empowerment Statistical Quality Control Attitude Toward Risk	Communication Design for Manufacturability Management of Materials Strategy Emphasizing Product Quality Training and Education
Non-Significant	Supplier Relations Experiment of Design Worker Involvement Training and Education Hierarchical Organizational Structure	Management Participation Attitude Toward Risk Statistical Quality Control Supplier Relations Concurrent Engineering Experiment of Design Worker Empowerment Worker Involvement Hierarchical Organizational Structure

Research Question #5 was answered using factor analysis to summarize the patterns of correlations among the 14 variables and reduce the number of observed variables to five suprafactors. These are Personnel Environment, Strategic Planning, Operational Control and Process Improvement, Product Design and Development, and Hierarchical Organizational Structure.

The use of regression analysis addressed Research Questions #6, #7, and #8. The five suprafactors identified in Research Question #5 were regressed. Statistically significant level was established at $p < .10$.

Four of the suprafactors; Personnel Environment, Strategic Planning, Operational Control and Process Improvement, Product Design and Development, were determined to be statistically significant which answered Research Questions #6 and #7. The amount of variance in product quality explained by the four suprafactors was .16804.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

PRODUCT QUALITY SURVEY

Please respond to each statement below in terms of how strongly you agree or disagree. Remember you are only evaluating your manufacturing plant. **Use a No. 2 pencil only.** Fill each circle completely to indicate your choice. I simply want your opinion; there are no right or wrong answers. If you do not have a response or do not know the answer, please leave the statement blank.

	Statement	STRONGLY DISAGREE 1	2	3	4	5	6	STRONGLY AGREE 7
1	Management promotes the use of quality control tools (such as X-bar charts, R charts, process control charts, etc.) in manufacturing processes.	①	②	③	④	⑤	⑥	⑦
2	Management has received adequate training on how to use quality control tools (such as: X-bar charts, R charts, process control charts, etc.).	①	②	③	④	⑤	⑥	⑦
3	Customer focus is emphasized in determining product quality.	①	②	③	④	⑤	⑥	⑦
4	The product quality policy emphasizes the need for continuous improvement.	①	②	③	④	⑤	⑥	⑦
5	The product quality policy emphasizes the need for employee involvement.	①	②	③	④	⑤	⑥	⑦
6	Adequate resources (finances, people, time) are allocated for product quality improvement efforts to be successful.	①	②	③	④	⑤	⑥	⑦
7	Adequate resources (finances, people, time) are allocated for process quality improvement efforts to be successful.	①	②	③	④	⑤	⑥	⑦
8	Management is held accountable for achieving product quality goals.	①	②	③	④	⑤	⑥	⑦
9	Management receives timely data and information on product quality.	①	②	③	④	⑤	⑥	⑦
10	Product quality performance data (such as scrap rate and productivity levels, etc.) are collected and reported to departments in the organization.	①	②	③	④	⑤	⑥	⑦
11	Cost of product scrap is tracked and reported.	①	②	③	④	⑤	⑥	⑦
12	Cost of product rework is tracked and reported.	①	②	③	④	⑤	⑥	⑦
13	Cost of product defects is tracked and reported.	①	②	③	④	⑤	⑥	⑦
14	Data from a variety of external sources (customers, competitors, suppliers, etc.) are used in the strategic planning process.	①	②	③	④	⑤	⑥	⑦
15	Competitive benchmarking is used to develop product quality improvement plans.	①	②	③	④	⑤	⑥	⑦
16	Information about product performance and quality is systematically collected in order to identify root causes of customer problems.	①	②	③	④	⑤	⑥	⑦
17	There is a systematic short-term (one year or less) product quality planning process that describes performance goals.	①	②	③	④	⑤	⑥	⑦
18	There is a systematic intermediate-term (more than one year and less than five years) product quality planning process that describes performance goals.	①	②	③	④	⑤	⑥	⑦
19	There is a systematic long-term (five years to ten years) product quality planning process that describes performance goals.	①	②	③	④	⑤	⑥	⑦
20	Management at all levels is involved in the product quality planning process.	①	②	③	④	⑤	⑥	⑦
21	Employees are involved in the product quality planning process.	①	②	③	④	⑤	⑥	⑦
22	Customers are involved in the product quality planning process.	①	②	③	④	⑤	⑥	⑦
23	Suppliers are involved in the product quality planning process.	①	②	③	④	⑤	⑥	⑦
24	Customer requirements and expectations of the company's product(s) are used in developing strategic plans and goals.	①	②	③	④	⑤	⑥	⑦
25	Progress toward achieving quality goals is monitored for most of the company's product(s).	①	②	③	④	⑤	⑥	⑦
26	Product quality improvement plans include all functional areas (marketing, finance, operations, etc.) of the organization.	①	②	③	④	⑤	⑥	⑦
27	Suppliers meet most of the company's quality requirements.	①	②	③	④	⑤	⑥	⑦
28	Human resource programs that integrate product quality goals with employee training are in place.	①	②	③	④	⑤	⑥	⑦

Item	STRONGLY DISAGREE					STRONG AGR
29 There are effective and timely methods of communicating quality/performance goals and progress to line workers.	1	2	3	4	5	6
30 There is an effective system for communicating product quality problems to management.	1	2	3	4	5	6
31 Management gives timely feedback regarding employees' product or process quality improvement suggestions.	1	2	3	4	5	6
32 There is a structured curriculum for training all levels of employees in the use of quality improvement tools, such as statistical process controls and equipment process capabilities.	1	2	3	4	5	6
33 Employees are evaluated on their continual professional development.	1	2	3	4	5	6
34 Most employees believe the company is serious about improving product quality.	1	2	3	4	5	6
35 There is a systematic process to translate customer requirements into new/improved products.	1	2	3	4	5	6
36 Causes of product scrap and rework are identified.	1	2	3	4	5	6
37 Corrective action is taken immediately when a product quality problem is identified.	1	2	3	4	5	6
38 The product quality management system is periodically audited for effectiveness.	1	2	3	4	5	6
39 Key processes are systematically improved to achieve better product quality and performance.	1	2	3	4	5	6
40 Primary (key) suppliers have a quality assurance plan or manual with a written set of procedures.	1	2	3	4	5	6
41 There has been steady improvement in product quality during the last three years.	1	2	3	4	5	6
42 New products have been developed during the last three years that have positively affected market share or income.	1	2	3	4	5	6
43 There has been a steady reduction in the amount of product scrapped during the last three years.	1	2	3	4	5	6
44 There has been a steady reduction in the amount of product that has needed reworking during the last three years.	1	2	3	4	5	6
45 There has been a steady reduction in the amount of product rejected during the last three years.	1	2	3	4	5	6
46 There has been a steady decline in the number of warranty claims during the last three years.	1	2	3	4	5	6
47 There has been a steady decline in the number of product litigation claims during the last three years.	1	2	3	4	5	6
48 There has been a steady decline in the number of customer complaints during the last three years.	1	2	3	4	5	6
49 Information is collected and maintained concerning the company's product(s) to demonstrate quality improvements in goods and services.	1	2	3	4	5	6
50 There is a systematic process to accurately determine customers' requirements and expectations.	1	2	3	4	5	6
51 Customers' complaints concerning product quality go to the appropriate personnel for quick resolution.	1	2	3	4	5	6
52 There is an effective process for determining future product requirements and expectations of the company's customers.	1	2	3	4	5	6
53 Customer service employees are empowered to resolve customers' complaints quickly.	1	2	3	4	5	6
54 Customers believe the company's product and/or service guarantees are superior to the competition's.	1	2	3	4	5	6
55 There is an overall high level of customer satisfaction with products and/or services.	1	2	3	4	5	6
56 The company has objective measurements of customer satisfaction.	1	2	3	4	5	6
57 Measures of customer satisfaction are reliable.	1	2	3	4	5	6
58 Customer satisfaction ratings have shown steady improvement over the last three years.	1	2	3	4	5	6

	Statement	STRONGLY DISAGREE						STRONGLY AGREE
59	Comparisons between the company's and its competitors' customer satisfaction ratings have been made over the last three years.	①	②	③	④	⑤	⑥	⑦
60	Quality improvement teams are used to help increase product quality.	①	②	③	④	⑤	⑥	⑦
61	Production schedules are consistently met.	①	②	③	④	⑤	⑥	⑦
62	Inventory has decreased over the last three years.	①	②	③	④	⑤	⑥	⑦
63	Manufacturing processes are more automated now than three years ago.	①	②	③	④	⑤	⑥	⑦
64	Experiment of design techniques, i.e., Taguchi, are used to improve product design.	①	②	③	④	⑤	⑥	⑦
65	Employees inspect their work for defects.	①	②	③	④	⑤	⑥	⑦
66	Employees have the authority to halt the production process.	①	②	③	④	⑤	⑥	⑦
67	Products are easier to manufacture and/or assemble today than three years ago.	①	②	③	④	⑤	⑥	⑦
68	Each level of management knows and understands the manufacturing process for each product.	①	②	③	④	⑤	⑥	⑦
69	Departmental managers frequently discuss quality problems with employees in the department.	①	②	③	④	⑤	⑥	⑦
70	Management and workers openly discuss production problems.	①	②	③	④	⑤	⑥	⑦
71	An integral part of the company's competitive strategy is based on producing a quality product.	①	②	③	④	⑤	⑥	⑦
72	Independent decision making by employees is encouraged in the company.	①	②	③	④	⑤	⑥	⑦
73	Management and workers trust each other.	①	②	③	④	⑤	⑥	⑦
74	Materials are purchased from suppliers whose quality has been formally certified.	①	②	③	④	⑤	⑥	⑦
75	There is a quality improvement training program for employees.	①	②	③	④	⑤	⑥	⑦
76	Employees are trained to do more than one job.	①	②	③	④	⑤	⑥	⑦
77	Concurrent engineering methods are used to design new products.	①	②	③	④	⑤	⑥	⑦
78	There are regularly scheduled meetings with primary (key) suppliers.	①	②	③	④	⑤	⑥	⑦
79	Managers are instructors in the product quality improvement training programs.	①	②	③	④	⑤	⑥	⑦
80	The product quality program has led to an increased number of workers' suggestions to improve product and/or process quality.	①	②	③	④	⑤	⑥	⑦
	The company's product quality program has improved:							
81	Rate of return on investment.	①	②	③	④	⑤	⑥	⑦
82	Market share.	①	②	③	④	⑤	⑥	⑦
83	Manufacturing productivity.	①	②	③	④	⑤	⑥	⑦
84	Level of customer satisfaction.	①	②	③	④	⑤	⑥	⑦
85	Internal product reliability. (The product(s) is/are performing as expected (tested) at the factory.)	①	②	③	④	⑤	⑥	⑦
86	External reliability of the product. (The product(s) is/are performing as expected in the hands of the consumer.)	①	②	③	④	⑤	⑥	⑦
87	The manufacturing processes are controlled by statistical process controls.	①	②	③	④	⑤	⑥	⑦
88	Products are manufactured in a cellular type production equipment layout.	①	②	③	④	⑤	⑥	⑦

	STRONGLY DISAGREE						STRONGLY AGREE
89 Managers are creative problem solvers.	①	②	③	④	⑤	⑥	⑦
90 The company is significantly committed to Total Quality Management or a similar Total Quality Program.	①	②	③	④	⑤	⑥	⑦
• **The company's product quality improvement program has decreased the:**							
91 Scrap rate.	①	②	③	④	⑤	⑥	⑦
92 Rework rate.	①	②	③	④	⑤	⑥	⑦
93 Internal defects rate.	①	②	③	④	⑤	⑥	⑦
94 Warranty work.	①	②	③	④	⑤	⑥	⑦
95 Product liability cost.	①	②	③	④	⑤	⑥	⑦
96 Number of customers' complaints.	①	②	③	④	⑤	⑥	⑦
97 Time it takes to design a new product.	①	②	③	④	⑤	⑥	⑦
98 Number of components in your products.	①	②	③	④	⑤	⑥	⑦

• **For the following statements, fill in the circle corresponding to the letter indicating your answer.**

99 What percentage of the workers' quality improvement suggestions are implemented?
(A) 0% (B) 1-19% (C) 20-39% (D) 40-59% (E) 60-79% (F) 80-100% — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

100 What percentage of your customers are repeat customers?
(A) 0 to <20% (B) 20 to <40% (C) 40 to <60% (D) 60 to <80% (E) 80 to 100% — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

101 Within your industry, would you rate your plant's product quality as:
(A) Superior (B) Above Average (C) Average (D) Below Average (E) Poor — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

102 Your plant location is ISO _______ registered.
(A) 9001 (B) 9002 (C) 9003 (D) Not Registered — Ⓐ Ⓑ Ⓒ Ⓓ

103 *Is your company a:*
(A) Sole Proprietorship (B) Closely Held Corporation (C) Sub S Corporation
(D) Partnership (E) Publicly Traded Corporation (F) *Other* _______________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

104 What is the number of employees at your location?
(A) 50-250 (B) 251-500 (C) 501-750 (D) 751-1000
(E) 1001-1500 (F) 1501-2000 (G) **If > 2000, state the number.**__________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

105 How many levels of management are between line workers and the highest level of management at your plant location?
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6 (F) 7 (G) **If > 7, then how many.** __________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

106 Five years ago, how many levels of management were between line workers and the highest level of management at your plant location?
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6 (F) 7 (G) **If > 7, then how many.** __________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

107 Number of years that your plant has had a formal quality program:
(A) 1 (B) 2 (C) 3 (D) 4 (E) 5 (F) 6 (G) 7
If > than 7 years, please enter the approximate number: __________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

108 The annual plant employee turnover rate is:
(A) <1% (B) 1 *to* <3% (C) 3 to <5% (D) 5 to <7% (E) 7 to <9% (F) 9 to <11% (G) 11 to <13%
If > than 13%, please enter the approximate percentage: __________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

109 What are the company's annual sales (*in millions of dollars*)?
(A) <100 (B) 100-<250 (C) 250-<500 (D) 500-<1000
(E)1000-<1500 (F) 1500-<2000 (G) **If > 2000, state the approximate number.**__________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

110 What is the company's annual net income (in millions of dollars)?
(A) <5 (B) 5-15 (C) 16-25 (D) 26-35 (E) 36-45
(F) 46-55 (G) **If > than 55 million dollars, state the approximate number**_______ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

111 The percentage rate of return on investment over the last three years is:
(A) <0% (B) 0-3% (C) >3-6% (D) >6-9% (E) >9-12%
(F) >12-15% (G) >15-18% ***If > 18%, state the approximate amount**__________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

112 The market share percentage has increased over the last three years:
(A) <0% (B) 0-3% (C) >3-6% (D) >6-9% (E) >9-12%
(F) >12-15% (G) >15-18% ***If > 18%, state the approximate amount**__________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

113 Has manufacturing productivity increased over the last three years?
(A) <0% (B) 0-<10% (C) 10-<20% (D) 20-<30% (E) 30-<40%
(F) 40-<50% (G) 50-<60% ***If > 60% or < 0, state the approximate amount**__________ — Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ

114 Is your company unionized at your location? **(A) YES (B) NO** — Ⓐ Ⓑ

115 What products or product groups are manufactured at the plant?
List only the top three products or product groups.

_______________ _______________ _______________

Thank you for your thoughtful responses to this questionnaire and for taking the time to be part of this research. If you have any comments, please put them on an additional sheet of paper and return it with your questionnaire.

APPENDIX B

COVER LETTERS

October 3, 1995

Dear Manager,

As part of my doctoral dissertation, I am currently conducting a study to determine the critical factors that influence product quality in a manufacturing environment. Your participation in this research will help address important product quality issues and will allow me to complete the requirements for a Doctor of Philosophy in Business Administration from the Fogelman School of Business and Economics at The University of Memphis.

You were chosen for this survey because of your working knowledge of product quality and your manufacturing experience. I recognize that you're a busy person; therefore, I have developed a questionnaire that you can complete in approximately twenty minutes, plus or minus five minutes. Please limit your answers to your plant location (not other plants or divisions in your company).

You may be assured of complete confidentiality. The identification number will simply enable me to track the questionnaire when you return it to us. Your name will never be placed on the questionnaire. All publication of the data will be presented as group data with individual responses kept in confidence.

The results of this research will be made available to the American Society for Quality Control. You can receive a summary of results by writing your name, address, and "copy of results requested" on the back of the return envelope. Please do not put this information on the questionnaire itself.

I will be most happy to answer any questions you might have. Please write or call. The telephone number is (901) 683-5259.

Sincerely,

Paul Dreyfus

Postcard

October 10, 1995

Last week, I mailed you a questionnaire seeking your input concerning product quality in manufacturing. If you have already completed and returned it to me, please accept my sincere thanks. If not, I urge you to do so today. Because this questionnaire has only been sent to a small but representative sample of manufacturing managers, your response is extremely important if the results are to accurately represent opinions concerning product quality in manufacturing.

If, by some chance, you have not received the questionnaire, or it has gotten misplaced, please call me right now, collect (901-683-5259) and I will get another one in the mail to you today.

Sincerely,

Paul Dreyfus

October 24, 1995

Dear Manager,

About three weeks ago, I wrote to you seeking your opinion concerning product quality in manufacturing. As of today, I have not yet received your completed questionnaire.

My research was undertaken because of the belief that manufacturing managers are interested in finding out what the critical factors are in producing a quality product. This research will help direct your efforts to the critical few factors that can improve product quality and increase your ability to compete.

I am writing to you again because of the significance each questionnaire has to the usefulness of this study. Your name was selected through a scientific sampling process from the membership list of the American Society for Quality Control. In order for the results of this study to be truly representative of the opinions of manufacturing managers in the U.S., it is essential that each person in the sample return his or her questionnaire.

In the event that your questionnaire has been misplaced, a replacement is enclosed. Your cooperation is greatly appreciated.

Sincerely,

Paul Dreyfus

November 14, 1995

Dear Manager,

I am writing to you about my study to determine the critical factors that influence product quality. I have not received your completed questionnaire.

The large number of questionnaires returned is very encouraging. But, whether I will be able to describe accurately how manufacturing managers feel about these important issues, depends on you and the others who have not yet responded. I say this because my experience suggests that those of you who have not yet sent in your questionnaire may hold quite different perceptions of product quality.

Since this is the first national survey using these criteria, the results will be of particular importance to American manufacturers. This new information will enable companies to gain a competitive advantage in the marketplace by improving product quality. But the usefulness of the results depends on how accurately I can identify and describe the critical factors.

I'll be happy to send a copy of the results if you would like one. Simply put your name, address, and "copy of results requested" on the back of the return envelope. I expect to have them ready to send by early Spring of 1996.

Your contribution to the success of this study is greatly appreciated.

Sincerely,

Paul Dreyfus

APPENDIX C

TABLES

Table 1

Correlation table of the 14 variables for the total sample

	GTD	STRAT	MP	RISK	COMM	HMGMT	QSPC	MM
GTD	1.000	.565	.580	.549	.623	.064	.424	.453
STRAT	.565	1.000	.688	.531	.664	.086	.462	.390
MP	.580	.688	1.000	.629	.714	.106	.530	.440
RISK	.549	.531	.629	1.000	.630	.110	.373	.394
COMM	.623	.664	.714	.630	1.000	.081	.452	.472
HMS	.064	.086	.106	.110	.081	1.000	.099	.007
QSPC	.424	.462	.530	.373	.452	.099	1.000	.306
MM	.453	.390	.440	.394	.472	.007	.306	1.000
SREL	.463	.585	.570	.466	.519	.026	.425	.516
CENG	.474	.444	.480	.454	.421	-.024	.334	.384
EOD	.347	.401	.352	.336	.337	.066	.466	.281
DM	.453	.350	.427	.378	.374	.015	.288	.336
WI	.420	.450	.507	.510	.510	.054	.346	.284
TE	.539	.656	.741	.585	.657	.125	.587	.451
WE	.524	.452	.543	.664	.614	.071	.351	.398

	SREL	CENG	EOD	DM	WI	TE	WE
GTD	.463	.474	.347	.453	.420	.539	.524
STRAT	.585	.444	.401	.350	.450	.656	.452
TMP	.570	.480	.352	.427	.507	.741	.543
RISK	.466	.454	.336	.378	.510	.585	.664
COMM	.519	.421	.337	.374	.510	.657	.614
HMGMT	.026	-.024	.066	.015	.054	.125	.071
QSPC	.425	.334	.466	.288	.346	.587	.351
MM	.516	.384	.281	.336	.284	.451	.398
SREL	1.000	.502	.414	.375	.365	.561	.428
CENG	.502	1.000	.397	.517	.372	.465	.359
EOD	.414	.397	1.000	.327	.276	.407	.239
DM	.375	.517	.327	1.000	.378	.361	.360
WI	.365	.372	.276	.378	1.000	.505	.461
TE	.561	.465	.407	.361	.505	1.000	.479
WE	.428	.359	.239	.360	.461	.479	1.000

Table 2

Cronbach Alpha Scores for the Independent, Dependent Variables, and Baldrige Award Categories

Independent Variables	Alpha Score
Quality Strategy	.80
Management Participation	.74
Attitude Towards Risk	.79
Communication	.85
Statistical Quality Control	.78
Management of Materials	.70
Suppier Relationship	.65
Concurrent Engineering	.65
Design for Manufacturability	.53
Worker Involvement	.71
Training and Education	.70
Worker Empowerment	.66
Dependent Variables	
Conformance	.95
Reliability	.87
External Failure	.87
Baldrige Award Categories	
Leadership	.88
Information and Analysis	.88
Strategic Quality Planning	.92
Human Resource Development and Management	.89
Management of Process Quality	.84
Quality and Operations Results	.85
Customer Focus and Satisfaction	.89

Table 3

Correlation table of the 14 variables for the subsample

	GTD	STRAT	MP	RISK	COMM	HMGMT	SPC	MM
GTD	1.000	.297	.268	.250	.350	.111	.151	.267
STRAT	.297	1.000	.460	.304	.395	.144	.230	.202
MP	.268	.460	1.000	.459	.552	.151	.318	.297
RISK	.250	.304	.459	1.000	.460	.115	.114	.231
COMM	.350	.395	.552	.460	1.000	.154	.068	.238
HMGMT	.111	.144	.151	.115	.154	1.000	.133	.021
SPC	.151	.230	.318	.114	.068	.133	1.000	.153
MM	.267	.202	.295	.231	.238	.021	.153	1.000
SREL	.260	.416	.334	.269	.281	.134	.209	.384
CENG	.131	.263	.205	.226	.117	-.006	.138	.212
EOD	.132	.268	.155	.148	.007	.105	.471	.111
DM	.221	.075	.206	.183	.138	-.048	.153	.217
WI	.159	.158	.246	.272	.331	.048	.127	.115
TE	.302	.408	.527	.325	.336	.095	.419	.300
WE	.235	.148	.323	.525	.387	.151	.087	.242

	SREL	CENG	EOD	DM	WI	TE	WE
GTD	.260	.131	.132	.221	.159	.302	.235
QSTRAT	.416	.263	.268	.075	.158	.408	.148
MP	.334	.205	.155	.206	.246	.527	.323
RISK	.269	.226	.148	.183	.272	.325	.525
COMM	.281	.117	.007	.138	.331	.336	.387
HMGMT	.134	-.006	.105	-.048	.048	.095	.151
QSPC	.209	.138	.471	.153	.127	.419	.087
MM	.384	.212	.111	.217	.115	.300	.242
SREL	1.000	.401	.272	.254	.134	.399	.261
CENG	.400	1.000	.344	.476	.122	.242	.100
EOD	.302	.344	1.000	.274	.119	.310	.044
DM	.225	.476	.274	1.000	.254	.167	.179
WI	.124	.122	.119	.254	1.000	.268	.302
TE	.355	.242	.310	.167	.268	1.000	.295
WE	.224	.100	.044	.179	.302	.295	1.000

Table 4

Frequency Table of Experiment of Design for the Subsample

Value Label	Value	Frequency	Valid Percent	Cum Percent
	1.0	175	27.5	27.5
	2.0	126	19.8	47.3
	3.0	97	15.3	62.6
	4.0	85	13.4	75.9
	5.0	80	12.6	88.5
	6.0	53	8.3	96.9
	7.0	20	3.1	100.0

The question asked for the respondents was:

Experiment of design techniques, i.e., Taguchi, are used to improve product design.

Table 5

Correlation table of the eight statistically significant variables (GROUP) correlated with the five non-significant variables for the total sample

	GTD	HMGMT	SREL	EOD	WI	TE	GROUP
GTD	1.000	.067	.477	.352	.408	.537	.676
HMGMT	.067	1.000	.027	.076	.058	.132	.083
SREL	.477	.027	1.000	.412	.374	.559	.701
EOD	.352	.076	.412	1.000	.289	.408	.474
WI	.408	.058	.374	.289	1.000	.512	.778
TE	.537	.132	.559	.408	.512	1.000	.756
GROUP	.676	.083	.701	.474	.778	.756	1.000

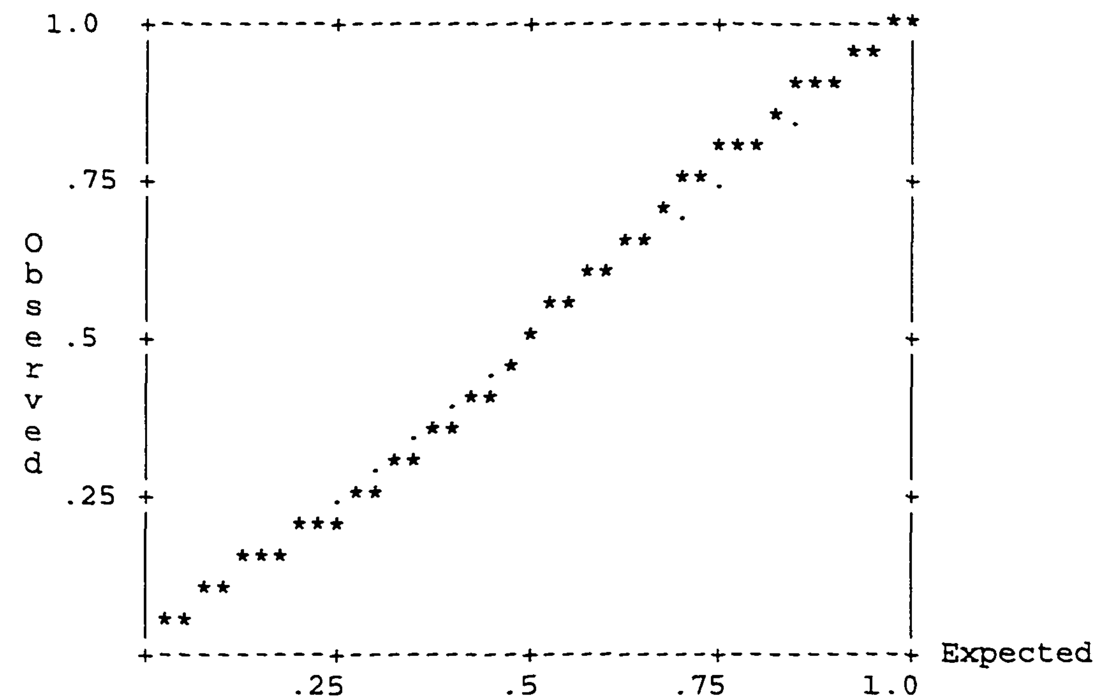
APPENDIX D

FIGURES

```
  N  Exp N       (* = 2 Cases,     . : = Normal Curve)
  0    .47   Out
  0    .93  3.00
  0   2.37  2.67 .
  7   5.41  2.33 **:*
 18  11.08  2.00 *****:***
 14  20.29  1.67 *******  .
 21  33.30  1.33 ***********     .
 50  48.96  1.00 ***********************:*
 58  64.47   .67 *****************************  .
 95  76.04   .33 **************************************:*********
103  80.35   .00 ***************************************:************
 76  76.04  -.33 *************************************:
 55  64.47  -.67 ****************************    .
 36  48.96 -1.00 ******************      .
 26  33.30 -1.33 *************    .
 17  20.29 -1.67 *********.
 10  11.08 -2.00 *****.
 11   5.41 -2.33 **:***
  6   2.37 -2.67 :**
  3    .93 -3.00 **
  1    .47   Out *
```

```
N     = The actual number of respondents in the sample.
Exp N = The expected number of respondents in the sample.
*     = 2 respondents.
.  :  = Points on a normally distributed Curve.
```

Figure 3. A histogram of a normal distribution overlaid with the total sample distribution standardized residual.



* = The sample standardized residuals.
. = The graph of the model's line of regression.

Figure 4. Normal probability plot of the standardized residual of the total sample.

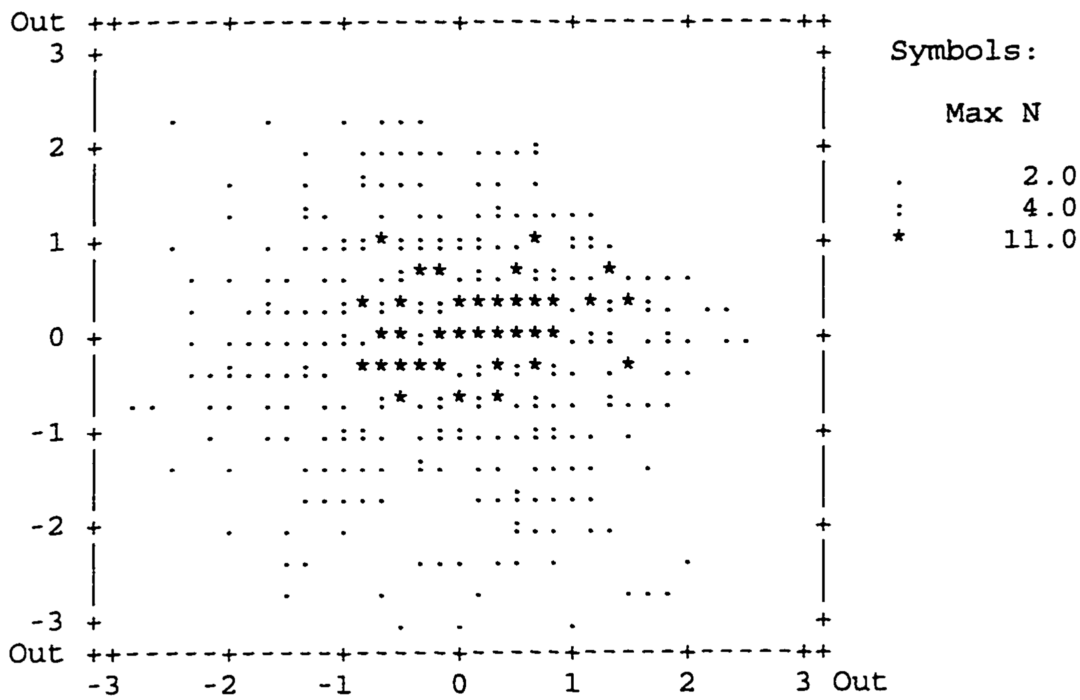
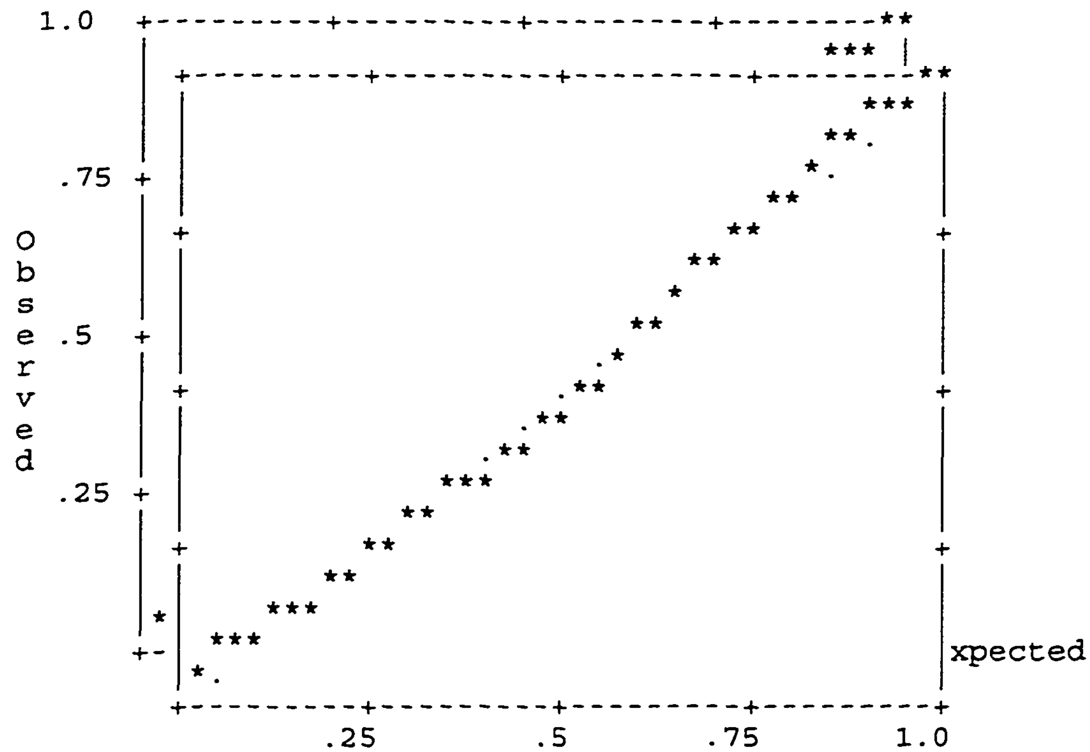


Figure 5. Standardized scatterplot of the residuals from the total sample.

```
 N Exp N      (* = 1 Cases,     . : = Normal Curve)
 0    .20   Out
 0    .41  3.00
 0   1.04  2.67 .
 1   2.36  2.33 *.
 4   4.84  2.00 ****.
 6   8.86  1.67 ******  .
14  14.54  1.33 **************.
25  21.37  1.00 ********************:****
32  28.15   .67 ***************************:****
39  33.20   .33 ********************************:******
42  35.08   .00 **********************************:*******
25  33.20  -.33 *************************       .
22  28.15  -.67 **********************     .
17  21.37 -1.00 *****************   .
15  14.54 -1.33 **************:
 6   8.86 -1.67 ******  .
 6   4.84 -2.00 ****:*
 5   2.36 -2.33 *:***
 2   1.04 -2.67 :*
 4    .41 -3.00 ****
 0    .20   Out
```

```
N     = The actual number of respondents in the sample.
Exp N = The expected number of respondents in the sample.
*     = 1 respondent.
.  :  = Points on a normally distributed Curve.
```

Figure 6. A histogram of a normal distribution overlaid with the standardized residual of companies with a Baldrige score in the top forty percentile.



* = The sample standardized residuals.
. = The graph of the model's line of regression.

Figure 7. Normal probability plot of the standardized residual of companies with a Baldrige score in the top forty percentile.

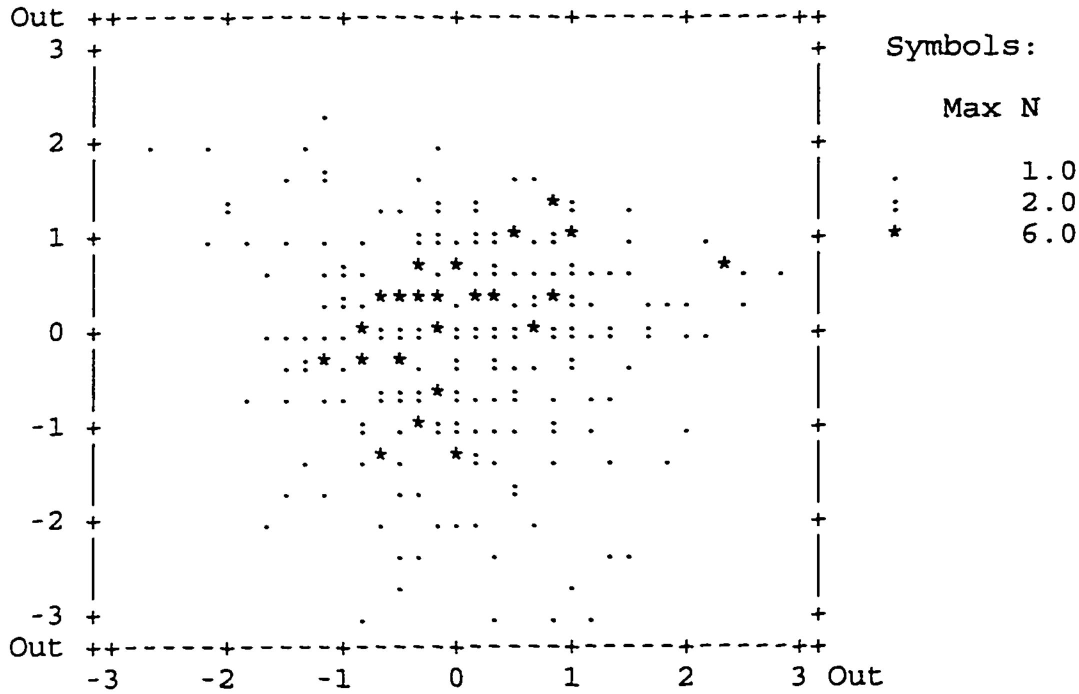


Figure 8. Standardized scatterplot of the residuals of companies with a Baldrige score in the top forty percentile.

APPENDIX F

GLOSSARY

GLOSSARY

ATTITUDE TOWARD RISK	The management's feelings (trust) with regard to employees' independent decisions related to product/process quality issues.
CONCURRENT ENGINEERING*	A concept that refers to the participation of all the functional areas of the firm in the product design activity. Such a process should ensure that the final design meets all the needs of the stakeholders and should ensure a product that can quickly be brought to the marketplace while maximizing quality and minimizing costs.
EMPLOYEE EMPOWERMENT*	The practice of giving nonmanagerial employees the responsibility and the power to make decisions regarding their jobs or tasks. It is associated with the practice of transfer of managerial responsibility to the employee. Empowerment allows the employee to take on the responsibility for tasks normally associated with staff specialists.
EMPLOYEE INVOLVEMENT*	The concept of using the experience, creative energy, and intelligence of all employees by keeping them informed, and including them and their ideas in decision-making processes appropriate to their areas of expertise.
DESIGN FOR MANUFACTURABILITY	A measure of the design of a product or process in terms of its ability to be produced easily, with fewer parts, and higher quality.

* Cox, J. F., Blackstone, J. H, Jr. Spencer, M. S., Terry, C. H., & Terry, M. V. (Eds.). (1992). APICS dictionary (7th ed.). Falls Church, VA: American Production and Inventory Control Society.

All others defined by the author.

EXPERIMENT OF DESIGN	An experiment which extracts information about several design factors more efficiently than a traditional single-factor experiment (Ross, 1988).
MANAGEMENT and PARTICIPATION	A process in which management is directly activitly involved in training employees in quality techniques and are knowledgeable regarding manufacturing processes.
STRATEGY EMPHASIZING PRODUCT QUALITY	A collective pattern of decisions that acts upon the formulation and deployment of corporate resources. To be most effective, the corporate strategy emphasising product quality, involving manufacturing functional area, should act in support of the overall strategic direction of the business and provide for competitive advantages.
MANAGEMENT OF MATERIALS*	The grouping of management functions supporting the cycle of material flow, from the supplier to the internal control of production materials.
SUBOPTIMIZATION*	A problem solution that is best from a narrow point of view but not from a higher or overall company point of view.
RELIABILITY*	The probability of a product performing its specified function under prescribed conditions without failure for a specified period of time. It is a design parameter that can be made part of a requirements statement.

* Cox, J. F., Blackstone, J. H, Jr. Spencer, M. S., Terry, C. H., & Terry, M. V. (Eds.). (1992). APICS dictionary (7th ed.). Falls Church, VA: American Production and Inventory Control Society.

All others defined by the author.

STATISTICAL QUALITY CONTROL*	The use of statistical techniques in the quality function. This generic term includes such individual techniques as control charts and statistical process control.

* Cox, J. F., Blackstone, J. H, Jr. Spencer, M. S., Terry, C. H., & Terry, M. V. (Eds.). (1992). APICS dictionary (7th ed.). Falls Church, VA: American Production and Inventory Control Society.

All others defined by the author.