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An instrument for operationalizing and testing Deming's theory of Total Quality Management

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Temple University, 1993

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A Dissertation
Submitted to
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in Partial Fulfillment
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DOCTOR OF PHILOSOPHY

by
Nabil Tamimi
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CHAPTER 1

INTRODUCTION

1.1 Background

Interest in quality issues has been rising recently as firms come to realize that providing better quality leads to lower costs due to reductions in appraisal and failure costs (Garvin, 1983; Williams, 1984) and higher market share (Buzzell and Wiersema, 1981; Craig and Douglas, 1982; Phillips, Chang, and Buzzell, 1983). The quality literature is full of prescriptions that offer various remedies to cure the ailing quality of U.S. products. Such remedies suggest the use of different statistical techniques to determine acceptance sampling rules and to develop mathematical models to identify the critical factors affecting quality.

More recently, the focus has shifted towards examining the role of management in creating a quality planning environment to complement the use of statistical and optimization techniques. Such an environment encourages teamwork, communication, pride of workmanship, leadership, and continuous improvement,and emphasizes the role of the employee (Deming, 1982; Crosby, 1979), and the customer (Garvin, 1983; Warne, 1985; Walton, 1986; Wachniak, 1990).

Deming (1982), best known for his work in Japan that created a revolution in quality, defined his theory of management for quality in terms of fourteen principles. Crosby (1979) also recommended 14 steps to successfully implement a quality improvement program. Both Deming and Crosby recognize the role of top management as a critical factor to any successful quality planning environment. Ishikawa (1982) developed the Cause and Effect diagram to examine the roles of workers, methods, machines, and materials in reducing variations. Juran (1986) emphasized quality planning, quality control, and quality improvement as three basic essentials of quality management. Others advocated adopting the Just In Time philosophy (Schonberger and Gilbert, 1983; Schonberger, 1984; Warne, 1985; Ansari, 1986; Ansari and Modarress, 1990; Newman, 1988; Ebrahimpour and Lee, 1988), in order to develop closer ties between firms and suppliers for better quality.

1.2 Purpose of the Study

The existing literature lacks operational measures of the critical factors of quality management and models linking such factors to quality performance. For example, although top management commitment has been prescribed by many quality experts as one of the critical factors of organizational quality management, few have attempted to show how to measure it or implement it. Consequently, there is little proof of how much this or any other factor contributes to the success of a quality program. In responding to a questionnaire asking "What type of research study would help you do your job better?", thirty percent of the quality improvement professionals said that they would like research on how to implement the quality process and what practices contribute to a successful quality program (Lewis and Mink, 1992).

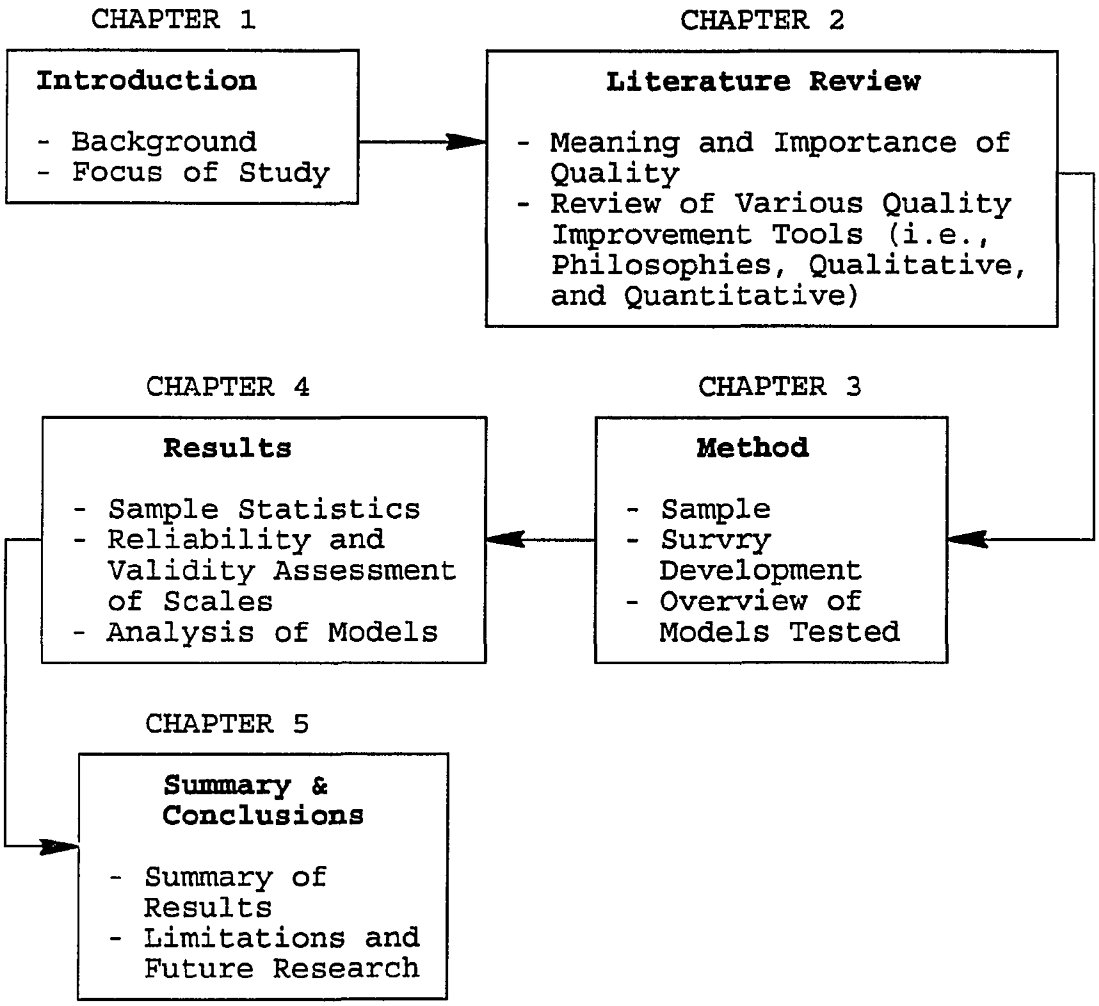
Saraph, Benson, and Schroeder (1989) were the first to operationalize the measurements of eight critical factors (management leadership, role of the quality department, product/service design, supplier quality management, process management, quality data and reporting, employee relationships, and training) that they synthesized from the quality literature as determinants of "Total Quality Management" (TQM). TQM is a comprehensive philosophy in which every person within the organization shares responsibility for quality. Fundamental to TQM implementation is top management commitment, achieving continuous improvement in customer satisfaction, and adopting quality as a strategic philosophy.

Although Deming's philosophy has been praised by many quality experts as the road map to implementing the Total Quality Management philosophy, there is little guidance in the quality literature on how to measure or implement Deming's practices. Moreover, no empirical research has yet tested the impact of the Deming philosophy on quality performance, or examined the inter-relationships among Deming's practices. Therefore, to shed a new light on understanding the Deming philosophy, the focus of this study is to:

1) Develop survey measures of Deming's fourteen principles using perceptual data collected from a sample of manufacturing and service type firms. Such measures can then be used by industry practitioners and decision makers to assess the status of quality management, diagnose training needs, prioritize improvement areas for efficient allocation of resources, and build models that relate Deming's principles to various performance measures such as improved quality, productivity, market share, profitability, and employees' morale, 2) develop a causal model linking Deming's fourteen principles to firms' quality performance. Statistical tests are conducted to test the significance of each individual principle and the significance of the model as a whole; 3) determine if there are sufficient relationships among Deming's fourteen principles to extract a second-order factor resembling "Total Quality Management" (TQM). Specifically, whether the different dimensions of Deming's philosophy form an overall construct (i.e., TQM) is tested by conducting a second-order factor analysis.

Figure 1 outlines the systematic approach used in conducting the research study. As shown in Figure 1, Chapter 2 reviews the quality literature, Chapter 3 discusses the sample selection and the rationale behind the operationalization of Deming's factors, and provides an overview of the models to be tested. Chapters 4 and 5 provide the results and the conclusions of the study, respectively.

Figure 1: Outline of Research Study



CHAPTER 2

LITERATURE REVIEW

This chapter briefly reviews the different operational definitions of quality, quality's linkage to market share and costs, and the various tools (philosophies, qualitative, and quantitative) that are commonly applied to identify and improve quality problems.

2.1 Meaning of Quality

The following definitions demonstrate the various dimensions of quality.

"Fitness for use." (J. M. Juran, ed., Quality Control Handbook, 1974, p. 2)

"Conformance to specifications." (P. B. Crosby, Quality Is Free, 1979, p 15)

"Differences in quality amount to differences in the quantity of some desired ingredient or attribute." (L. Abbott, Quality and Competition, 1955, pp. 126-127)

All the above meanings of quality show the wide definition of quality. Garvin (1984) believes that definitions of quality fall into several categories; Some definitions, such as Juran's, are said to be user-based. They suggest that quality is in the eyes of the customers. Manufacturing-based definitions, such as Crosby's, suggest that quality means conformance to standards and specifications. Other definitions, such as Abbott's, are said to be product-based and view quality as a precise and measurable variable. For example fine rugs have a large number of knots per square inch.

Townsend (1986) distinguishes between two types of quality: Quality in Fact vs. Quality in Perception. Quality in Fact, typically used in manufacturing, refers to the product's conformance to designed specifications, while Quality in Perception, typically used in marketing, refers to how the product is perceived by the customer.

Garvin (1984), focusing on product quality, divides it into eight dimensions: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Garvin further emphasizes the importance of targeting one's own niche by focusing on an untapped dimension of quality for a competitive strategy.

Parasuraman, Zeithmal, and Berry (1985) focusing on service quality found that customers assess service quality in terms of:

- reliability
- responsiveness
- competence
- access
- courtesy
- communication
- credibility
- security
- knowing the customer
- tangibles

Table 2.1 provides a brief explanation of each of the above determinants of service quality.

Table 2.1: Determinants of Service Quality

Explanations of Determinants of Service Quality
Reliability involves consistency of performance and dependability. It means that the firm performs the service right the first time and also means that the firm honors its promises. •Accuracy in billing •Keeping records correctly •Performing the service at the designed time
Responsiveness concerns the willingness or readiness of employees to provide service. It involves timeliness of service, such as •Mailing a transaction slip immediately •Calling the customer back quickly •Giving prompt service
Competence means possession of the required skills and knowledge to perform the service. It involves •Knowledge and skill of the contact personnel •Knowledge and skill of operational support personnel •Research capability of the organization
Access involves approachability and ease of contact. It means •The service is easily accessible •Waiting time to receive service is not extensive •Convenient hours of operation •Convenient location of service facility
Courtesy involves politeness, respect, consideration, and friendliness of the contact personnel. It includes •Consideration of the consumer's property •Clean and neat appearance of contact personnel

Table 2.1 (continued):

Explanations of Determinants of Service Quality

Communication means keeping customers informed in language they can understand and listening to them. It may mean that the company has to adjust its language for different consumers. It involves

- Explaining the service itself
- Explaining how much the service will cost
- Assuring the consumer that a problem will be handled

Credibility involves trustworthiness, believability, honesty. It involves having the customer's best interests at heart. Contributing to credibility are

- Company name
- Company reputation
- Personal characteristics of the contact personnel

Security is the freedom from danger, risk, or doubt. It involves

- Physical safety
- Financial security
- Confidentiality

Understanding/Knowing the customer involves making the effort to understand the customer's needs. It involves

- Learning the customer's specific requirements
- Providing individualized attention
- Recognizing the regular customer

Tangibles include the physical evidence of the service, such as

- Physical facilities
- Appearance of personnel
- Tools or equipment used to provide the service
- Physical representations of the service
- Other customers in the service facility

Source A Parasuraman, Valerie A Zeithmal, and Leonard L. Berry, "A Conceptual Model of Service Quality and its Implications for Future Research," Journal of Marketing, Fall 1985, p. 44.

2.2 Importance of Quality

In the last few years, there has been a great focus on quality because firms came to realize that providing a quality product or service can be translated into greater profits as a result of lower costs and larger market share.

Empirical studies examining the relationship between quality and market share have shown a positive direct correlation between the two. Buzzel and Wiersema (1981a, 1981b) have found that among companies achieving substantial market share gains (5% or higher annual increases), nearly half reported at least moderate improvements in relative quality Craig and Douglas (1982) have also studied the association between market share and various marketing mix variables such as product quality, advertising, promotional expenditures, relative price, and sales force expenditures Their findings have revealed that product quality was the most important variable yielding the largest contribution in all regression analyses. Similar findings were also obtained by Phillips, Chang and Buzzell (1983) supporting the premise that product quality influences ROI (Return On Investment) via its effect on market position.

The other linkage between quality and increased profits via cost savings has produced mixed results depending on how quality and costs were defined. Crosby (1979) in his famous "Quality is Free" book classified quality costs into prevention costs, appraisal costs and failure costs.

Prevention costs include design reviews, drawing checking, training, quality audits, and preventive maintenance costs. Appraisal costs, incurred in ensuring that the product or service conforms to designed specifications, include inspection and testing, supplier surveillance, packaging inspection, and status measurement and reporting. Failure costs, commonly broken down into internal and external failures, include rework, scrap, redesign, warranty, and product liability.

When quality was defined as added features or aesthetics, and costs were expressed in terms of direct manufacturing costs (e g., labor hours, raw materials, etc.), studies have shown that a direct proportional relationship exists between quality and cost (Gale and Branch, 1982). In other words, better quality resulted in higher costs. However, when quality was defined as conformance to designed specifications and costs were expressed in terms of Crosby's failure costs, studies have shown that an inverse relationship exists between quality and cost (Gilmore, 1974; Garvin, 1984; Williams, 1984). In other words, better quality resulted in lower costs. Such findings were confirmed by Garvin (1983) in a comparative study of the room air-conditioning industry in the U.S. and Japan. Garvin found that Japanese manufacturers with defect rates between fifteen and seventy times lower than U.S. competitors, had total rework, scrap, and warranty costs that were, on the average, 1.3 percent of sales. The best American companies had total rework, scrap, and warranty costs that were 2.8 percent of sales. Similar findings were also obtained by Williams (1984) after Stacoswitch Co. of California launched its quality improvement program. Appraisal, prevention, and failure costs were reduced by 21% in the second year, and by an additional 13% in the third year.

Taguchi (Ross, 1988), on the other hand, views the costs of quality in a different manner. He identifies two categories of costs associated with providing sub-optimal products: losses incurred by the society (e.g. pollution), and losses incurred due to deviating from the designed target values. However, no empirical research work has attempted to associate Taguchi's costs with firms' performance.

2.3 Quality Control/Management Philosophies

2.3.1 Deming's Philosophy

Deming (1982), one of the first to develop and apply quality management, identified fourteen points to be implemented in quality programs to be successful. They are.

1) Creating constancy of purpose for improvement of product and service through innovations, research and development, and education.

2) Adopting quality as management's new philosophy.

3) Ceasing dependence on mass inspection by building quality into the product, and by using statistical control techniques to minimize reliance on mass inspection.

4) Ending the practice of awarding business based on price tag alone.

5) Improving constantly the system of production and service by tackling the sources of the problems and not the symptoms.

6) Instituting training and education in statistical improvement techniques, and in specific work-related skills for managers, supervisors and employees.

7) Instituting leadership whereby supervisors work to build the trust of their employees.

8) Driving out fear so that every one can work effectively for the company.

9) Breaking down barriers between staff areas and departments to achieve common goals.

10) Eliminating slogans and targets for the workforce asking for new levels of productivity without providing methods since targets are meaningless in an unstable environment (i.e. malfunctioning equipment, poor lighting, and incompetent supervision).

11) Eliminating numerical quotas that prevent workers from producing quality products.

12) Removing barriers to pride in workmanship.

13) Instituting a vigorous program of education and retraining where management and workers are continuously trained in communications, team-work, conflict resolution, etc.

14) Taking action to accomplish the transformation through creating a structure that will promote the above 13 points.

2.3.2 Crosby's Program

For a quality program to be successful, Crosby (1979) identified the following sequence of steps to be implemented by management:

1) Management commitment to develop and implement a comprehensive quality policy plan.

2) Creating a quality improvement team to run and execute the quality improvement program.

3) Establishing quality measures such as number of defects or number of complaints to determine the quality status of the firm, and to identify non-conformance problems.

4) Quantifying the price of conformance and non-conformance by establishing an appraisal, prevention, and failure cost accounting system.

5) Emphasizing quality awareness by sharing with employees the cost of non-conformance, and communicating the importance of establishing a quality program.

6) Taking corrective action to identify the means of correcting the quality problems.

7) Planning for the zero-defects day whereby management would reveal to all employees their total quality commitment.

8) Educating and training all employees.

9) Setting a zero-defects day whereby management conveys to its employees the philosophy of "do it right the first time", and demonstrates its commitment to quality.

10) Allowing employees to set their own goals that are to be accomplished.

11) Devising a system to eliminate the obstacles to zero defects.

12) Recognizing through rewards those employees who meet their set goals.

13) Creating quality councils to conduct regular meetings of the quality improvement team and to ensure that plans are progressing as established.

14) Doing it over again by striving for continuous quality improvement.

2.3.3 The Just In Time (JIT) Philosophy

The practice of JIT reflects its title. Materials are purchased or produced in small lot sizes in exact quantities just when needed. Small lot sizes lowers storage costs, decreases inventory, and exposes quality problems sooner (Schonberger, 1984).

Repeat business with few nearby suppliers, another JIT feature, encourages supplier loyalty and long term agreement, decreases the risk of supply interruptions, lowers buyers bidding costs, and improves quality at the source (Schonberger and Gilbert, 1983).

Involving suppliers in the design process itself can also lead to lower costs due to cheaper redesigns or looser tolerances on the design parameters since the greater the input of the supplier the less likely that problems will occur later in the development stage (Newman, 1988).

In a cross-sectional survey by Ansari and Modarress (1987) to identify the potential benefits of JIT purchasing for U.S. manufacturers, it was revealed that the greatest degree of improvement was in product quality followed by increased productivity.

Ansari's (1986) survey of U.S. companies implementing the JIT philosophy has revealed that purchasing in small lot sizes, and establishing long-term relationships with suppliers were critical JIT factors that contributed to improving quality.

At Omrak Industries of Portland, Oregon, productivity improved 25% to 40% when their production line was converted from the traditional "Just In Case" system to the JIT system. Warne (1985) attributes this successful improvement in productivity to easier detection of non-conformities, elimination of work-in-progress inventories, and lower lead times from suppliers.

Ebrahimpour and Lee (1988) performed a detailed study of quality improvement programs in electronic manufacturing firms in the U.S. and found that all firms surveyed selected their vendors based on price <u>and</u> on their ability to deliver quality and timely materials.

2.4 Qualitative Quality Control/Management Tools

2.4.1 Cause-and-Effect Diagrams

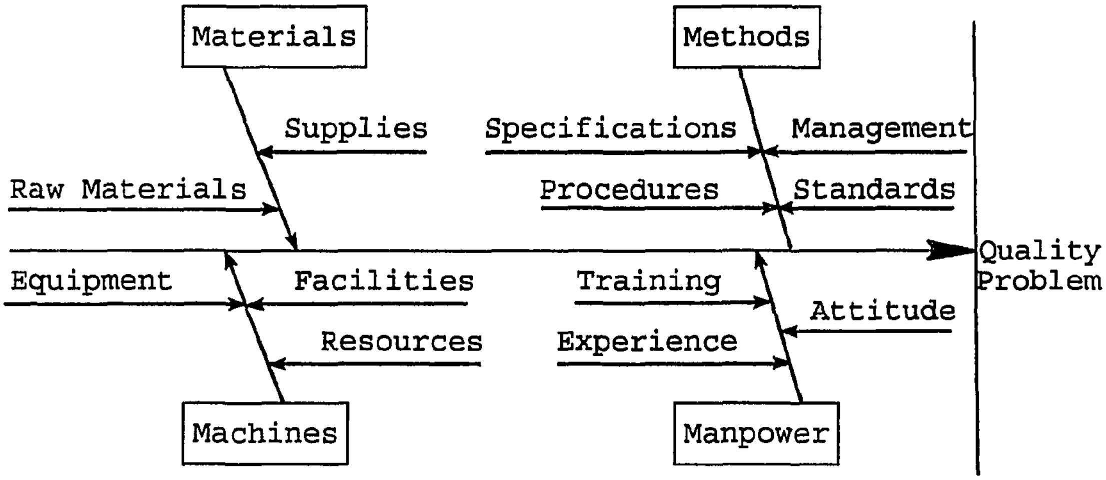
Cause And Effect Diagrams (CED) were developed by Kaoru Ishikawa of Japan in 1953 to identify and categorize all the potential causes of quality dispersion (effect). Ishikawa (1982) identified the following four causes (4 M's) that account for the variations in a quality characteristic:

1) Methods
2) Materials
3) Manpower
4) Machinery

Once a quality charecteristic problem has been isolated, efforts would be directed towards identifying the sources of this quality dispersion. Figure 2 shows an example of a typical CED representation. For instance, inadequate training, insufficient experience, and poor workers' attitudes are examples of quality dispersion sources associated with manpower depicted in the CED.

A cross-sectional field survey of U.S. manufacturing firms conducted by Modaress and Ansari (1989) revealed that 41% of the firms are using CED in manufacturing process control, 17% are using CED in design, and 16% are using CED in research and development.

Figure 2: An Example of a Cause-and-Effect-Diagram



2.4.2 Quality Circles

Quality circles (QC) are a technique of participative management that developed in Japan following World War II. A quality circle consists of a small group of volunteers within a company who do similar work and meet on a regular basis to identify, analyze, and solve problems in its members' work area (Hutchins, 1985). Cole (1983) reported on the success of quality circles as a device for production workers to feed back problems and solutions to the design sections. Cornell (1984) described the successful implementation of quality circles in the health care, insurance, banking, and airline industries. Increased employee morale, productivity, and savings were among the reported benefits resulting from implementing quality circles.

A three year intensive study of Japanese management systems by Warne (1985) has revealed that employee involvement and team spirit was one of the major activities that led to the Japanese manufacturing superiority.

Garvin's (1983) survey of the U.S. air-conditioning industry has revealed that at the U.S. company with the lowest service call rate, the president met weekly with all corporate vice presidents to review service call statistics and to discuss improvement strategies.

2.4.3 Competitors

Competitors are often important sources for quality improvement tools Unlike industrial espionage, observing how a competitor achieves higher product reliability through a better choice of technology, or higher sales through convenient packaging and service warranties can be a valuable guidance for the firm. Whiting (1991) defines benchmarking as a continuous process of comparing a company's products and processes with those of world leaders, learning how that excellence was achieved, and then setting out to match and surpass it.

For example, in 1979 the Xerox Corporation initiated a process called competitive benchmarking whereby competing copying machines were taken apart and scrutinized to assess the strengths and weaknesses of the competition (Camp, 1990). In 1982, Motorola Inc. was among the first to offer Japanese language courses to its managers in order to help them learn more about their Japanese competitors (Wiggenhorn, 1990).

2.4.4 Consumers

Customers can often be a very valuable source of information for quality improvement programs. Marketing research surveys and customers' complaints can act as valuable indicators of how customers perceive a given product or service.

By listening and responding to customer feedback on the quality of its carpets, Du Pont was able to generate over $2 billion in revenues when it launched its Stainmaster stain-resistant carpet (International Corporation, 1990). James Kearns, executive vice-president who heads the company's Fiber Department comments: "We did a lot of market research to figure out what bothered the customer most about carpets. We found out that stains irked people the most, and now we have engineered a product that addresses most common household food and beverage stains."

Ford Company, for example, in designing the "Taurus" relied on dealers' comments in making a user-friendly car based on observations made by salespeople. Insurance companies were also brought in to advise on the design to minimize the customer's expense in fixing a car after a collision (Walton, 1986).

In his survey of Japanese companies, Garvin (1983) observed the great commitment to consumers through creating internal consumer review boards whose function was to act as typical consumers in testing and evaluating products before shipments.

Warne (1985) observed that in Japan, the very first test for the Deming prize is, "How efficient is your feedback from the customer". In awarding the Malcolm Baldridge National Quality Award, 30 percent of the total possible points are awarded to companies that acknowledge customer's needs and expectations (Wachniak, 1990).

2.5 Quantitative Quality Control/Management Tools

2.5.1 Histograms

Histograms used in quality control are bar graphs of the frequency of occurrence of some value of a quality characteristic (i.e. thickness, hardness, number of defects) Their shape gives clues about the central tendency and the variation of the data with respect to specifications. Central tendency is usually measured by the average, mode or median, while dispersion is usually measured by the range or the standard deviation. One limitation of histograms, however, is the fact that they are static in nature and do not capture variations with time (Bhote, 1988).

Modarress & Ansari's survey (1989) of U.S. firms reveals that the frequency histogram is used by 69% of the firms in manufacturing processes, by 29% in design, and by 28% in research and development.

2.5.2 Pareto Charts

Pareto charts were developed by Italian economist Vilfredo Pareto, and converted into a quality improvement tool by J. Juran (Scholtes, 1989). Pareto charts are constructed similar to frequency distribution charts. The horizantal axis represents the different types of quality problems that .need improvement, while the vertical axis represents the frequency of occurrence for each problem. Thus, Pareto charts signal the vital few quality problems from the trivial many, so that resources can be focused on the critical few. Since sometimes a large number of defects may not represent a great amount of money lost while a small number of defects may represent a great deal of money lost, Ishikawa (1982) suggests to have the vertical axis representing amounts of money instead of frequency occurrence. Modarress & Ansari's (1989) survey of U.S. maufacturing firms shows that 59% of the firms are using Pareto charts in manufacturing process control, 26% are using Pareto charts in design, and 20% are using Pareto charts in research and development.

2.5.3 Control Charts

Unlike histograms which are static in nature, a control chart is a graphic presentation of data over time. A control chart is simply a visual graph of the time series behavior of a quality characterisatic. Control charts were first developed by W. Shewhart in 1924 to determine whether a process is in control through differentiating between random and non-random variations (Duncan, 1976). Runs (a run is a succession of items of the same class), trends, and cycles are typical non-random variations that are attributed to assignable causes (Ishikawa, 1982). Assignable causes are relatively large variations that are attributable to special causes generated, for example, by differences among machines, workers, or materials (Duncan, 1976).

A control chart's construction varies according to whether the data it contains is discrete (i.e. countable data such as the number of defects), or continuous (i.e. measurable data such as strength, weight, etc.). Furthermore, the sampling distribution of the data determines the mean of the process and its upper and lower control limits. Table 2.2 shows a list of common control charts used in practice with a description of the type of data they may contain and their associated sampling distributions (Duncan, 1976).

It should be noted that various time series forecasting methods (e.g , decomposition methods, ARIMA, state space models and intervention analysis) can be applied to control chart data to model the behavior of the process and to detect the existence of any non-random variations much before the process goes beyond its upper or lower control limits.

Modarress & Ansari's (1989) survey reveals that $\bar{X}$ and R charts are used by 76% of the manufacturers in process control, by 13% in design, and by 13% in research and development.

Table 2.2: Common Quality Control Charts Used in Practice

Type of Data	**Control Chart**	**Description**	**Distribution**
Discrete	p-chart	fraction defective	binomial
	np-chart	number of defectives	binomial
	u-chart	defects per sample	poisson
	c-chart	defects per unit	poisson
Continuous	$\bar{X}$-chart	monitors mean of process	normal
	R-chart	monitors process range	normal

Bhote (1988) emphasizes, however, that control charts are useful "maintenance tools" at best that indicate whether corrective action is needed or not, and in no way help in identifying the actual causes of quality problems. Ishikawa (1982) stresses that control charts can be powerful control tools if combined with his cause-and-effect diagrams in identifying the non-random variations.

2.5.4 Regression Analysis

Regression analysis is a statistical tool that establishes association among variables. This technique can be applied to improve product quality by investigating the relationship between a quality characteristic (the dependent variable), and other factors (the independent variables) that may influence the characteristic.

Duncan (1976, p. 745) states "if we know which factors are the important ones in producing variability in the quality of output and if we learn to what extent variation in a factor causes variation in quality of output, then we may, by controlling the variation in the factor, control variation in quality of output."

Hotard and Jordan (1981) explain that regression analysis can also be applied in quality control to indirectly measure a particular quality characteristic that requires costly or destructive testing by relating that quality characteristic to another less costly characteristic.

Modarress and Ansari's (1989) survey reveals that regression analysis is used by 39% of the firms for process control, 27% for research and development, and 25% for design engineering More modern and powerful alternatives to regression analysis for detecting association between quality characteristics and other factors include Vector-ARMA and multivariate state space methods.

2.5.5 Design Of Experiments (DOE)

This technique involves defining and investigating all possible conditions in an experiment involving many factors, to arrive at the best combination of treatment levels. Such techniques were first introduced by R. A. Fisher in the 1920's to the agricultural industry in order to determine optimum treatments for land to achieve maximum yields (Duncan, 1976) Taguchi applied such notions to quality engineering by stressing the fact that quality should be built and designed into the product and not inspected into it. Team interaction methods where employees, supervisors, and managers meet to hypothesize critical factors affecting quality are commonly employed in DOE Statistical techniques (e.g., ANOVA, regression analysis, etc.) are then used to determine the factors contributing most to the quality problem.

For example, before implementing the DOE as a quality improvement tool, nearly 4% of all crankshafts cast by General Motors of Canada (GM) at its Ontario plant failed quality tests for hardness when they came out of their molds (Blackwell, 1989). Using the DOE helped GM isolate the most important factors affecting crankshaft hardness yielding an estimated savings of almost C$700,000. The DOE tool has also been sucessfully applied in the chemical industry where arriving at the best paint coating was achieved by varying the concentrations of the different chemicals (i.e., the treatment levels) that make up the coating (Rooney, 1991).

Modarress and Ansari's (1989) survey shows that design of experiments are used by 30% of the firms in design and engineering, by 31% in research and development, and by 30% in manufacturing process control.

2.5.6 Operations Research Tools

Operations Research (OR) techniques have been commonly applied in manufacturing process control and inspection. A common problem in process control is the selection of input levels that will produce desirable output quality with trade-offs involved in meeting conflicting output specifications. Goal programming is one OR technique that has been successfully applied in manufacturing process control (Sengupta, 1981; Wei, Olson and White, 1990; Olson, 1990). For example Sengupta (1981) applied goal programming to a process control problem in the paper industry in which levels of inputs and process variables were to be fixed in order to meet required specifications of several output characteristics.

OR techniques have also been widely used in investigating numerous inspection strategies (Prybutok, Atkinson and Saniga, 1990; Johnson, Kotz and Rodriguez, 1990; Williams, Looney and Peters, 1990; Zhang and Gerchak, 1990; Lee and Rosenblatt, 1988; Kemp and Kemp, 1988). Modarress and Ansari's (1989) survey shows that OR techniques are used by 9% of the firms in process control, by 8% in design and engineering, and by 6% in research and development.

CHAPTER 3

METHOD

This section describes the steps that are implemented to operationalize Deming's fourteen factors in order to develop various linear regression models and a Linear Structural Relational (LISREL) model (Hayduk, 1987; Long, 1983b) linking Deming's factors to firm's quality performance.

3.1 Conceptual Basis for Questionnaire Development

A thorough literature review was conducted to define each of Deming's fourteen factors focusing on the writings of Aguayo (1990), Deming (1982, 1986), Gabor (1990), Gitlow (1990), and Walton (1986). These writings specifically focus on explaining and interpreting Deming's fourteen factors, and are representative of the literature on the Deming philosophy. Table 3 1 provides a brief definition of each factor based on the writings of the above authors, while Table 3.2 summarizes the meanings of the factors.

3.2 Sample

This study uses manufacturing and service oriented firms of different sizes in measuring subjects' responses to questions about the extent of implementation of Deming's fourteen principles and the firm's quality performance.

Table 3.1: Definitions of Deming's Factors Emphasized by Selected Authors

Factor	Aguayo (1990)	Deming (1982) (1986)	Gabor (1990)	Gitlow (1990)	Walton (1986)
Creating constancy of purpose	Investing in ideas and technologies.	Allocating resources for long term planning and education. Improving the design of product and service.	Evaluating the future needs of customers. Commitment to long term strategies.	Establishing a mission statement. Encouraging innovation and product improvement.	Allocating resources to research and education, product innovation, and continuous improvement.
Adopting the new philosophy	Changing the managerial philosophy of the company.	New transformation of top management.	Adopting quality as the new philosophy.	Altering the corporate structure.	Top management's commitment to quality.
Ceasing reliance on mass inspection	Ceasing reliance on on mass inspection to improve quality.	Reliance on mass inspection is ineffective and costly. Using statistical control techniques is more effective.	Ceasing dependence on mass inspection.	Relying on statistical evidence of quality.	Building quality into the product or service.
Ending the practice of awarding business based on price alone	Involving suppliers in the product development process.	Establishing long-term relationship with suppliers. Working towards single suppliers.	Establishing close relationship with suppliers.	Encouraging long-term, single-source relationships between buyers and vendors.	Developing long-term relationship of loyalty with single vendors.

Table 3.1 (continued):

Factor	Aguayo (1990)	Deming (1982) (1986)	Gabor (1990)	Gitlow (1990)	Walton (1986)
Improving constantly the system of production or service	Continually improving the process.	Understanding customers' needs.	Constantly defining and refining the wishes of consumers.	Reducing the difference between customers' needs and process performance.	Assessing competitors to improve the product or service.
Instituting training	Training employees in quality related matters.	Training employees in quality related matters.	Training employees in recognizing when a system is out of control.	Training employees in how to perform their jobs. Training employees in understanding the product or service.	Training all employees in control charts and in the significance of variation.
Instituting leadership	Recognizing how to help those who are in need of training. Helping employees without passing judgement.	Empowering supervisors to improve working conditions.	Transforming the role of a supervisor from a cop to a coach.	Understanding how the role of the employees fits the aims of the organization. Creating trust among employees.	Helping employees on the job.
Driving out fear	Eliminating fear of losing one's job.	Empowering employees to express new ideas and ask questions.	Reporting working conditions that interfere with quality.	Providing job security.	Calling attention to conditions that interfere with quality. Providing job security.

Table 3.1 (continued):

Factor	Aguayo (1990)	Deming (1982) (1986)	Gabor (1990)	Gitlow (1990)	Walton (1986)
Breaking down barriers between departments	Teaming in research, design, sales, and production.	Teaming in research, design, purchasing, and sales.	Cooperating on common objectives.	Pursuing the firm's unifying goals.	Teaming to solve problems.
Eliminating slogans and targets	Poor quality originates from the system and not the workforce.	Removing obstacles is the responsibility of management.	Managing by numbers focuses on the end goal rather than the process.	The system and its variation is the responsibility of top management.	Slogans fail to provide the means to meet goals.
Eliminating numerical quotas	Workers are unable to produce beyond the system's capability.	A goal beyond the capability of the system can not be reached.	Workers should not be subjected to quotas because they can work only as well as the system permits.	Work standards should consider both quality and quantity.	Defining the limits of the job rather than assigning arbitrary quotas.
Removing barriers to pride in workmanship	Providing clear goals and objectives. Eliminating pressure for short term results.	Providing adequate documentation on how to do the job. Eliminating merit ratings.	Eliminating merit and annual ratings.	Eliminating annual or merit ratings. Providing Providing adequate supervision and training.	Providing workers with the proper equipment and supplies.

Table 3.1 (continued):

Factor	Aguayo (1990)	Deming (1982) (1986)	Gabor (1990)	Gitlow (1990)	Walton (1986)
Instituting education and self-improvement	Providing resources to develop employees skills for future needs.	Providing training that is directed towards long term needs.	Instituting a program of education and self-improvement.	Encouraging education in team building, conflict resolution and consensus in decision-making.	Encouraging training in skills that are not directly related to specific tasks.
Taking action to accomplishing the transformation	Hiring trained consultants to help in the transformation process.	Executing plans aimed at improving quality.	Making the improvement policy plans visible to all employees.	Helping employees in understanding the mission of the company.	Seeking the expertise of quality consultants. Educating employees about the importance of quality.

Table 3.2: Deming's Principles of Quality Management

Deming's Principle	**Explanation of Deming's Principle**
1 **Creating constancy of purpose**	Firm's emphasis should not be on short term profits. Long term objectives must be based on product or service improvement, through innovations, research and development, and education.
2. **Adopting the new philosophy**	Management should embrace quality as a philosophy. Viewing of quality management as a profit generating mechanism.
3. **Ceasing dependence on mass inspection**	Ceasing reliance on mass inspection by building quality into the product. Using statistical quality control techniques to minimize reliance on mass inspection.
4. **Ending the practice of**	Relying on few suppliers. Involving suppliers in the product or service development process. Establishing long-term relationships with suppliers.
5. **Constantly improving**	Quality improvement is a continuous process. Analyzing customers' needs. Acting upon customers' evaluations to improve the product or service. Investigating competitors' positions.
6. **Instituting training**	Training employees, supervisors, and managers in the use of statistical quality control techniques.
7. **Instituting leadership**	Improving supervision. Building trust between supervisors and employees. Increasing effectiveness of supervisors in handling work problems.

Table 3.2 (continued):

Deming's Principle	**Explanation of Deming's Principle**
8. **Driving out fear**	Allowing employees to express new ideas. Firm's adherence to continuous employment. Reducing employees' fear of making mistakes.
9. **Breaking down barriers between departments**	Coordinating activities among departments. Seeking common goals among departments.
10. **Eliminating slogans and exhortations**	Ceasing reliance on slogans and targets for the workforce
11 **Eliminating numerical quotas**	Emphasis should be on quality not quantity. Eliminating management by numbers.
12. **Removing barriers to pride in workmanship**	Adequate documentation on how to do the job. Clarity of goals set for employees. Less reliance on performance appraisals to rank employees.
13. **Instituting education**	Educating managers and employees in communications, self-confidence, team-work, and conflict resolution.
14. **Taking action to accomplish the transformation**	Acting towards executing quality improvement plans by adopting the above thirteen points.

Division managers are appropriate subjects for this survey since they are usually the adopters and implementers of company policies, and thus have interaction with both top management and employees. In developing an instrument to measure the critical factors of quality management, Saraph, Benson, and Schroeder (1989) used division managers as their subjects since they were assumed to be the "thought" leaders with respect to quality management in their business units.

In some firms, more than one response was sought from each firm, since quality practices are implemented in more than one division or department within the same company (e.g., manufacturing, accounting, engineering, human resources, etc.). Thus, each division is treated as a "business unit" in this study. Moreover, to investigate how the managers' responses compare with the hourly employees, 11 divisions from different organizations were selected and one hourly employee from each division was requested to complete the questionnaire.

For reasons of practicality and convenience, many firms were chosen from the Philadelphia Area Council for Excellence (PACE) network directory. As a council of the Greater Philadelphia Chamber of Commerce, PACE develops and promotes total quality efforts in the Delaware Valley, and provides opportunities for the transfer of knowledge about total quality among its members.

One potential disadvantage associated with using PACE members is their high degree of commitment to quality. In particular, the variances of the variables are reduced if the responses to the survey items measuring Deming's principles cluster in a positive direction (i.e., high top management commitment, good working environment, significant investment in training employees). Hence, the degree of association between Deming's factors and quality performance may be dampened.

Firms were stratified by type (service versus manufacturing) and 378 firms (225 service firms and 153 manufacturing firms) were randomly selected to participate in this study. A total of 184 respondents (173 division managers and 11 hourly employees) completed the survey, yielding a 46% response rate. The number of responses received from service type firms was 110, while the number of responses received from manufacturing type firms was 74.

3.3 Pilot Testing

Pilot testing is an integral part of questionnaire construction because it provides feedback on ease of completion and clarity. Thus, the questionnaire was exposed to various professors, students, and industry practitioners to test its clarity and completeness. Ambiguous questions were accordingly changed to improve their wording.

3.4 Survey Development and Measures

This section describes the measures that were used to operationalize Deming's principles, quality performance, and the covariates (i.e., the control variables) hypothesized to affect quality. The questionnaire along with the response scales used to measure the items are contained in Appendix A.

3.4.1 Measures of Deming's Principles

In developing the measures of Deming's principles, an extensive literature review was conducted to operationalize Deming's fourteen factors. In specific, attention was given to Deming's own interpretation of his philosophy (Deming, 1986, 1982), and the interpretations of other authors who have worked closely with Deming (Walton, 1986; Aguayo, 1990). Table 3 1 was used as the basis for developing the measures of Deming's principles.

To allow managers to respond to the survey items, a 5-point interval scale was used. The 5-point response scale had the following anchors: not at all true (0), slightly true (1), somewhat true (2), mostly true (3), and completely true (4).

The following items were developed to measure Deming's factors:

Factor 1: Creating constancy of purpose

1) Top management makes long-term plans.
2) Top management provides for research and development.
3) Top management provides for new technology.
4) Top management promotes employee training/education.

Factor 2: Adopting the new philosophy

5) Top management is committed to quality improvement as a way to increase profits.
6) Top management is committed to setting objectives for quality improvement.
7) Top management is committed to continuous quality enhancement as a primary goal.

Factor 3: Ceasing reliance on mass inspection

8) Suppliers use statistical quality control techniques.
9) Statistical control techniques are used to minimize reliance on mass inspection.
10) Top management supports the belief that quality must be "built into" the product and not "inspected into" it.

Factor 4: Ending the practice of awarding business based on price tag alone

11) Supplier selection is based on both quality and price rather than price alone.
12) Suppliers are involved in the product/service development process.
13) Long-term relationships are developed with suppliers.
14) There is reliance on a few dependable suppliers.

Factor 5: Improving constantly the system of production or Service

15) Customers' requirements are analyzed in the process of developing a product/service.
16) Customers' feedback is used to continually improve the product/service.
17) Top management assesses its competitors in order to improve the product/service.

Factor 6: Instituting Training

18) Employees are trained in statistical improvement techniques.
19) Employees are trained in quality-related matters.
20) Employees are trained in specific work-related skills.
21) Supervisors are trained in statistical improvement techniques.

Factor 7: Instituting leadership

22) Supervisors help their employees on the job.
23) Supervisors work to build the trust of their employees.
24) Supervisors lead in a way that is consistent with the aims of the organization.
25) Supervisors are viewed as coaches by their employees.

Factor 8: Driving out fear

26) Employees express new ideas related to improving work methods.
27) Employees seek their supervisors' assistance when unsure of their tasks.
28) Employees are not afraid to report working conditions that interfere with quality.
29) Employees feel they have job security.

Factor 9: Breaking down barriers between departments

30) Different departments have compatible goals.
31) In the product/service design process there is teamwork between different departments.
32) There is good communications between different departments.

Factor 10: Eliminating slogans and targets

33) Top management provides its workers with the methods/procedures to meet their goals.
34) Top management, not the hourly worker, is responsible for removing obstacles that cause defects/errors.
35) Top management does not use vague slogans (e.g., Do It Right The First Time) in communicating with its employees.

Factor 11: Eliminating numerical quotas

36) Work standards are based on quality and quantity rather than quantity alone.
37) Work standards are set based on process capability studies.
38) Numerical quotas are not given higher priority than quality of workmanship.

Factor 12: Removing barriers to pride in workmanship

39) Performance appraisals are not used to rank employees.
40) The quality of the working environment is good.
41) There is adequate documentation on how to do the job.
42) There is no pressure for short term results.
43) Top management sets realistic goals for its employees.

Factor 13: Instituting education and self-improvement

44) There are programs to develop team-work between employees.
45) There are programs to develop effective communications between employees.
46) There are programs to develop employees' conflict resolution skills.
47) There are programs to broaden employees' skills for future organizational needs.

Factor 14: Taking action to accomplishing the transformation

48) Top management takes action towards executing its quality improvement policies.
49) Top management makes its quality improvement policies visible to all employees.
50) Top management relies on internal or external consultants to implement its quality improvement policies

Note that various items were negatively worded in order to safeguard against "response bias" that may push respondents to answer questions in a specific direction. Negatively worded questions were recoded before analyzing the data to ensure consistency with the rest of the items. For example, on a five point response scale form 0 to 4, 0 was recoded to 4, 1 was recoded to 3, while 2 retained the same value. Next, the items (survey questions) were reorganized into five sections to help the respondent in identifying whether the statements refer to top management, hourly employees, suppliers, supervisors, or current practices.

3.4.2 Measures of Quality

In measuring the quality of a product or service, firms have relied on numerous measures tapping different quality dimensions. Garvin (1983), in a comparative study of the room air-conditioning industry in the U.S. and Japan, used failure rate costs (rework, scrap, and warranty costs) in measuring quality. Such measures of quality, incurred as a result of not doing the job right the first time, can be classified as "conformance-based" measurements. However, an accurate quality cost accounting system must be in place for the results to be meaningful.

Saraph, Benson, and Shroeder (1989) used customer satisfaction as the criterion for measuring quality performance. Such a measure can be classified as "consumer-based" since it relies on the notion that quality is what the buyer says it is, and not what the company says it is. Thus, measures tapping customers' complaints, repeat purchases, and customers' loyalty can be used as reflections of customers' satisfaction.

Other types of quality measures focusing on product or service characteristics such as features, reliability, or serviceability can be categorized as "attribute-based" measurements. These measures are based on the view that differences in quality amount to differences in the quantity of some desired ingredient or attribute (Abbott, 1955). For such measures to be most meaningful, firms can use characteristics of their competitors' products as a benchmark to compare their own quality characteristics.

Table 3.3 illustrates various quality measures that tap the above mentioned quality dimensions.

Table 3.3: Quality Measures

Consumer-based Measures:

- No. of customers satisfied
- No. of customers' complaints
- Customer retention rate
- Repeat Purchases
- Customer loyalty

Conformance-based Measures:

- Rework costs
- Warranty costs
- Scrap costs
- Defects rate
- Reductions in customers' returns

Attributes-based Measures:

- Features
- Reliability
- Serviceability
- Performance

In the present study, three perceptual measures (rated on a 5-point scale) were used to measure quality. The first measure indicated the firm's customer retention rate compared to the competition. This measure was intended to tap the consumer-based dimension. The anchors used in measuring this item were: inferior (1), below average (2), equal to the competition (3), better than average (4), and superior (5).

The second measure, intended to gauge the product's conformance to specifications (i.e., the conformance-based dimension), assessed the frequency of repeating work because it was not done correctly the first time. The anchors used in measuring this item were: never (1), seldom (2), sometimes (3), often (4), and always (5).

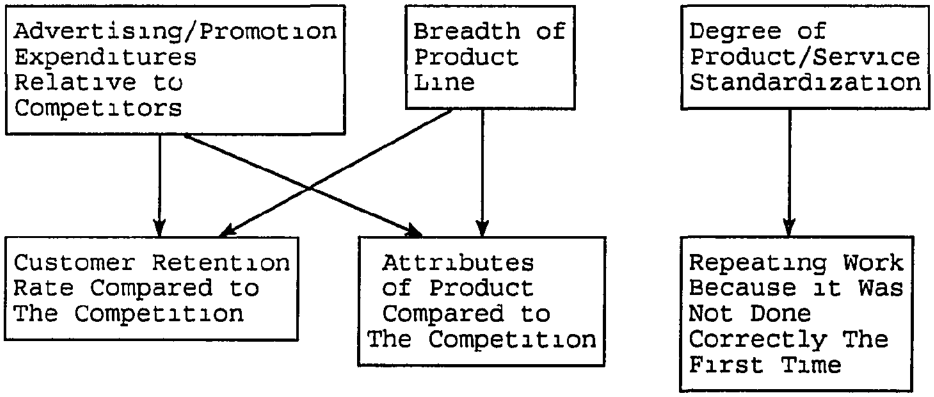
The third measure required managers to compare the attributes of their products or services in relation to their competitors. This measure was intended to tap the quality characteristic aspect of the product or service (i.e., the attribute-based dimension). The anchors used in measuring this item were: inferior (1), below average (2), equal to the competition (3), better than average (4), and superior (5).

These subjective measures were chosen over objective measures because of the difficulty in identifying and obtaining objective measures that would be appropriate for the different types and sizes of firms in the sample. For example, although consumers can provide an objective and an unbiased opinion regarding the quality of a given product or service, identifying such consumers can be a difficult task. Moreover, although measures such as number of defects or errors are objective measures of product conformance, however, a good accounting system must be in place to obtain this information. In addition, there is difficulty in comparing such numbers (i.e., defects) across different types of products. For instance, a defect in a microprocessor chip is costlier, to the producer and the consumer, than a defect in a pencil.

3.4.3 Measures of Covariates

To avoid model misspecification, it is necessary to control for the effects of other variables that may be correlated with quality performance in order to isolate the effect of Deming's philosophy on quality performance. Figure 3.1 shows the hypothesized covariates that were synthesized from the literature as possible factors affecting the quality performance measures used in this study.

Figure 3.1: Control Variables Affecting Quality Performance



In Figure 3.1, advertising/promotional expenses are hypothesized to have a positive impact on a firm's customer retention rate (i.e., the consumer-based quality dimension) and its customers' perceptions of the attributes of its product(s) (i.e., the attribute-based quality dimension). Increasing recognition of a brand name (i.e., brand awareness), and changing perceptions about the importance of brand/service attributes are two objectives commonly accomplished through aggressive advertising/promotion campaigns (Guiltinan and Paul, 1982). Furthermore, as shown in Figure 3.1, the breadth of the product line is expected to influence a firm's customer retention rate (i.e., the consumer-based quality dimension), and its customers' perceptions of the attributes of its product(s) (i.e., the attribute-based quality dimension). Breadth of the product line allows the firm to dominate its competitors within the product classification and creates entry barriers (Aaker, 1992).

For example, by offering nine brands of detergent, Procter & Gamble (P & G) is usually assured the largest share of detergent-selling space in a grocery store. In turn, this increases the chances that a given customer is able to find the desired attribute(s) (e.g., softness, scent, etc.) among the different brands. Moreover, the likelihood that customers switching from a P & G brand will end up choosing another P & G brand is greatly increased.

Finally, as depicted in Figure 3.1, the degree of the product or service standardization is expected to influence the frequency of repeating work because it was not done correctly the first time (i.e., the conformance-based quality dimension). For example, Garvin (1983) found that the U.S. plants with the lowest failure rates had the highest degree of standardization and the fewest design changes.

The covariate "advertising/promotion expenditure" was operationalized by asking division managers to respond to the survey question about the extent of their advertising/promotion expenditures relative to the competition. The anchors used in measuring this item are: much lower (1), somewhat lower (2), same as the competition (3), somewhat higher (4), and much higher (5). The covariate "breadth of the product line" was operationalized by asking division managers to respond to the question about the breadth of the product line (e.g., number of products/services offered) relative to the competition. The 5-point anchor scale used in measuring this item is: less broad than the competition (1), same as the competition (3), and much broader than the competition (5). The covariate "standardization" was operationalized by asking division managers to respond to the question about the degree to which the production or service process is standardized to reduce defects or errors. The anchors used in measuring this item are: not at all standardized (1), somewhat standardized (2), moderately standardized (3), mostly standardized (4), and very highly standardized (5).

3.5 Overview of Models to be Tested

Although variables of theoretical interest (latent variables) can not be directly observed, information about them can be obtained indirectly by noting their effects on observed variables (indicators). For example, Deming's first principle "creating constancy of purpose" is a latent variable that is measured by using four indicators (i.e., survey questions). A distinction is also commonly made between exogenous (independent) latent variables, and endogenous (dependent) latent variables. In this study, Deming's fourteen principles represent the exogenous latent variables, while quality (measured by three indicators) represents the endogenous latent variable.

The goals of the statistical analyses presented in this research are to:

1) test various structural models linking Deming's fourteen principles to quality.

2) determine if there are sufficient relationships among Deming's factors to extract a second-order factor resembling "Deming's Philosophy of Total Quality Management". Whether Deming's fourteen principles load on an overall construct resembling the "Deming Philosophy", often described as the Total Quality Management concept, can be tested using second-order factor analysis.

3) test a measurement model about the hypothesized links between the indicators and their respective Deming's factors.

It should be noted that if one is willing to assume that the observed indicators of the latent "quality" concept are true measures of quality, and similarly that the observed indicators of the latent Deming principles are true measures of these unobserved principles, then regression models may be used to address goals 1 and 2 above. Even if such an assumption is wrong, regression models may be used to measure the association between various indicators of quality and various indicators of Deming's principles. On the other hand, if one insists on modeling Quality and Deming's principles as latent concepts that are distinct from the indicators which measure them, then the statistical analysis technique LISREL (Linear Structural Relational Modeling) (Joreskog and Sorbom, 1989), can be used to address the goals 1-3 above.

3.5.1 Regression Models

A regression model of the form:

Quality Performance = f(Deming's Philosophy, Advertising/ Promotion Expenditures, Breadth of the Product Line, Degree of Product Standardization)

is used to determine the impact of Deming's philosophy on quality performance controlling for the effects of the above three covariates. First, the independent variable "Deming's Philosophy" is formed by summing respondents' scores to the survey questions measuring Deming's fourteen principles (i.e., Deming's Philosophy = X1+X2+X3+....+X50). This "additive" model estimates the <u>average</u> effect of Deming's principles on quality performance. Second, the independent variable "Deming's Philosophy" is formed by multiplying Deming's fourteen principles (i.e., Deming's Philosophy = F1*F2*F3*....*F14, where F1 = X1+X2+X3+X4, F2 = X5+X6+X7, etc.). This "multiplicative" model tests the principle that <u>all</u> of Deming's factors must be adhered to. The rationale behind testing the multiplicative effect of the Deming philosophy is to investigate whether all of Deming's principles must be rigorously applied to have an impact on quality performance, as advocated by Deming. Other regression models that test the individual significance of Deming's factors (rather than the philosophy as a whole) are also investigated.

3.5.2 LISREL Models

The hypothesized LISREL model can be mathematically represented as (dimensions of parameters are in parentheses):

$$\underset{(1\text{x}1)}{\eta} = \underset{(1\text{x}14)}{\Gamma} \underset{(14\text{x}1)}{\xi} + \underset{(1\text{x}1)}{\zeta} \qquad (3.1)$$

$$\underset{(50\text{x}1)}{x} = \underset{(50\text{x}14)}{\Lambda_x} \underset{(14\text{x}1)}{\xi} + \underset{(50\text{x}1)}{\delta} \qquad (3.2)$$

$$\underset{(3\text{x}1)}{y} = \underset{(3\text{x}1)}{\Lambda_y} \underset{(1\text{x}1)}{\eta} + \underset{(3\text{x}1)}{\epsilon} \qquad (3.3)$$

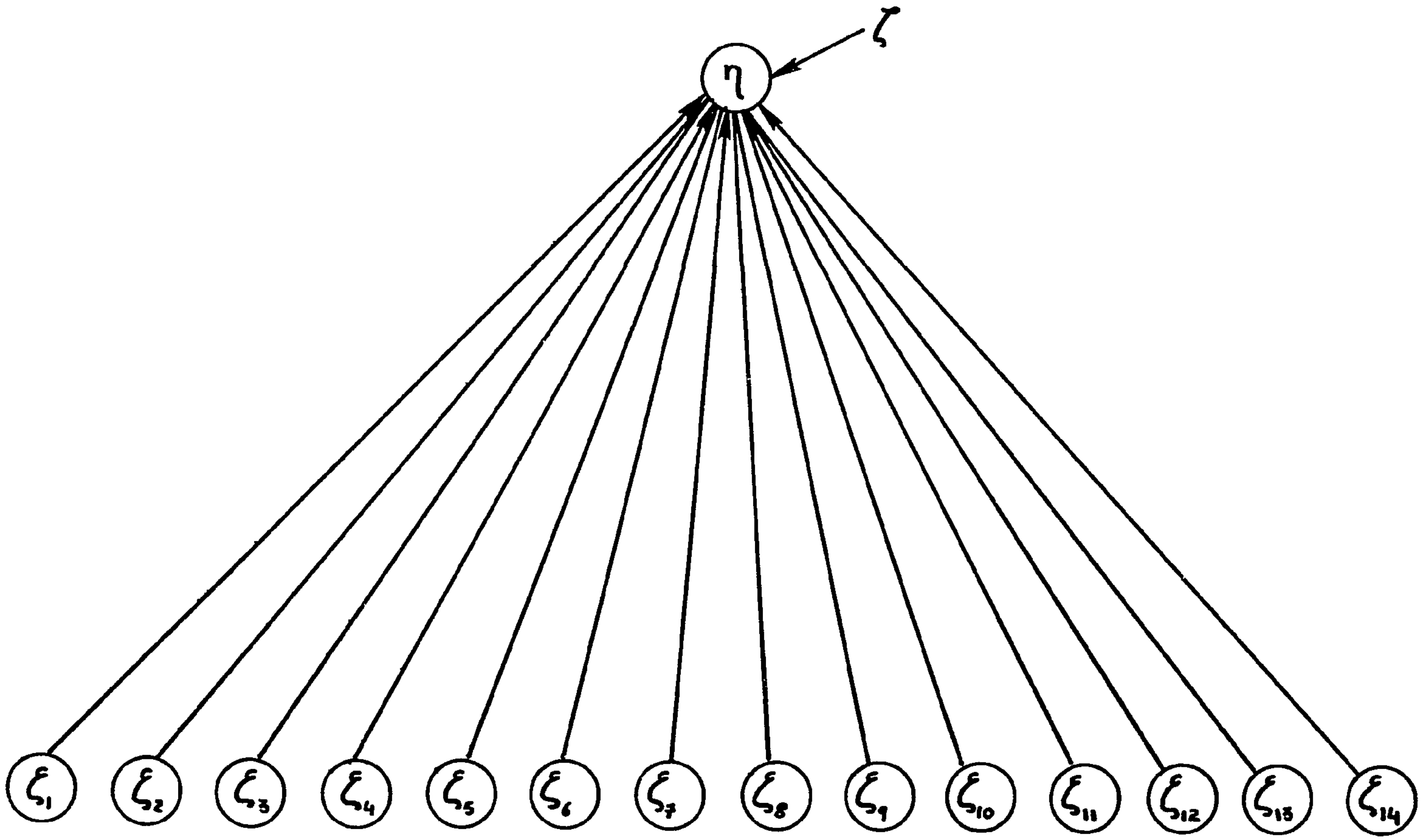
Equation 3.1, commonly known as the structural equation, expresses the endogenous latent variable η (quality performance) as a linear combination of the exogenous latent variables ξ (Deming's principles) and a random error variable ζ. The structural coefficients that indicate the influence of the exogenous latent variables on the endogenous latent variable are contained in Γ. All variables in the structural equation are assumed to be measured as deviations from their means: $E(\eta) = E(\xi) = E(\zeta) = 0$. A practical advantage of assuming zero means is that covariances are equivalent to expected values of the products of variables with zero means.

Furthermore, the errors and the exogenous latent variables are assumed to be uncorrelated in the structural equation. That is, $E(\boldsymbol{\xi}\boldsymbol{\zeta}) = \mathbf{0}$. Figure 3.2 illustrates the structural equation model. In this figure, the latent variables are represented by circles, and the straight arrows indicate that Deming's principles, $\boldsymbol{\xi}$'s, causally affect quality, $\boldsymbol{\eta}$.

The two remaining equations (3.2 & 3.3), commonly known as the measurement models, link the latent variables to their observed indicators. Equation 3.2 links the exogenous latent variables to their indicators, and equation 3.3 links the endogenous latent variable to its indicators. The elements in $\boldsymbol{\Lambda}$ represent structural coefficients linking the latent variables to their observed indicators. The vectors $\boldsymbol{\epsilon}$ and $\boldsymbol{\delta}$ are error variables specifying the cumulative effects of excluded variables and purely random measurement errors on the observed $\mathbf{x}$ and $\mathbf{y}$, respectively.

Both the observed and latent variables in the measurement equations are assumed to be measured as deviations from their means. Moreover, the errors in the measurement equations are assumed to have means of zero, in the same way that the errors in regression analysis are assumed to have means of zero. Thus, $E(\mathbf{x}) = E(\boldsymbol{\zeta}) = E(\boldsymbol{\xi}) = E(\mathbf{y}) = E(\boldsymbol{\epsilon}) = E(\boldsymbol{\eta}) = \mathbf{0}$. Furthermore, within each measurement equation, the latent variables and the errors are assumed to be uncorrelated. Specifically, it is assumed that $E(\boldsymbol{\xi}\boldsymbol{\delta}') = \mathbf{0}$ and $E(\boldsymbol{\eta}\boldsymbol{\epsilon}') = \mathbf{0}$. Although the δ's and ϵ's can be correlated among themselves

Figure 3.2: Structural Model

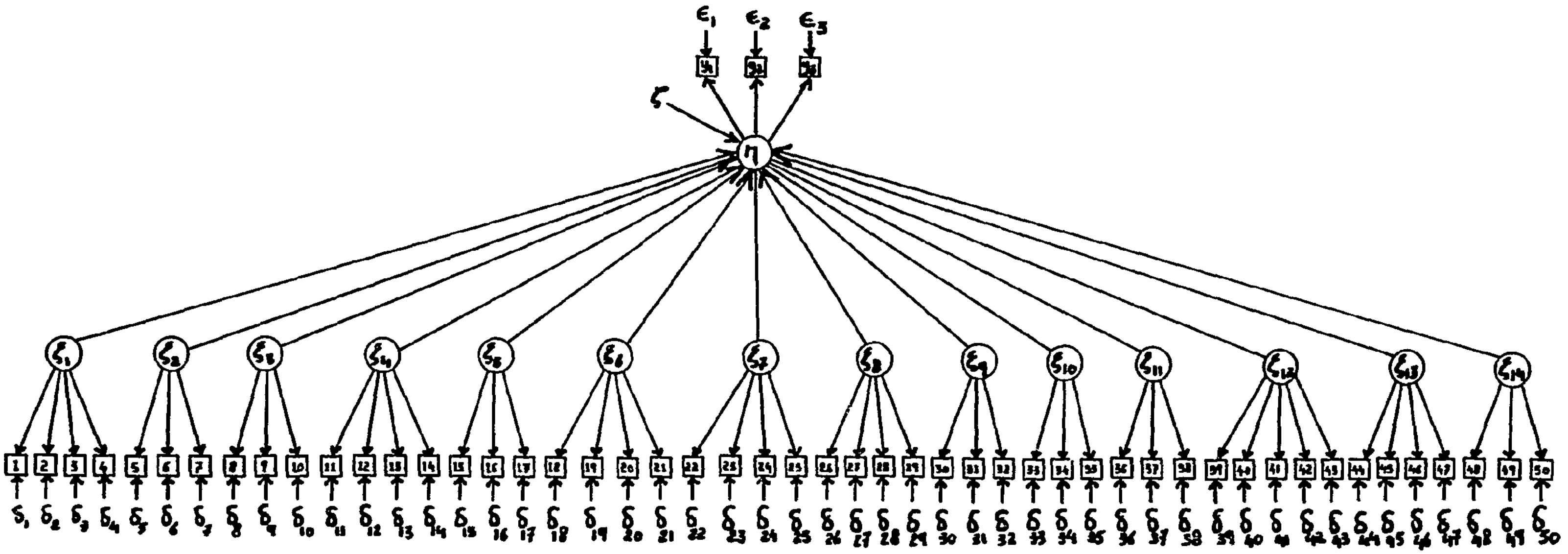


(i.e., no constraints are imposed on $E(\delta_i\delta_j)$ and $E(\epsilon_i\epsilon_j)$), it is assumed that the δ's and ϵ's are uncorrelated. Thus, $E(\boldsymbol{\delta}\boldsymbol{\epsilon}') = \mathbf{0}$. Moreover, just as the errors are assumed to be uncorrelated with the latent variables in their own equations, they are assumed to be uncorrelated with the latent variables in the other equation. Thus, it is assumed that $E(\boldsymbol{\xi}\boldsymbol{\epsilon}') = \mathbf{0}$ and $E(\boldsymbol{\eta}\boldsymbol{\delta}) = \mathbf{0}$.

In addition to the previously described matrices, LISREL defines four additional matrices: for the present study, $\boldsymbol{\Theta}_\delta$ is a (50x50) matrix of covariances among the δ errors in equation (3 2), $\boldsymbol{\Theta}_\epsilon$ is a (3x3) matrix of covariances among the errors ϵ in equation (3.3); $\boldsymbol{\Phi}$ is a (14x14) matrix of covariances among the exogenous variables (ξ's); and $\boldsymbol{\Psi}$ is a (1x1) variance matrix of the error ζ.

Figure 3.3 illustrates the combined structural and measurement models. In this figure, the observed indicators $(x_1, x_2, x_3, \ldots, x_{50}, y_1, y_2, y_3)$ are represented by squares, the latent variables $(\xi_1, \xi_2, \ldots, \xi_{14}, \eta)$ are represented by circles, and the error terms are expressed by the symbols δ_1, $\delta_2, \ldots, \delta_{50}$, ϵ_1, ϵ_2, ϵ_3, and ζ. A straight arrow pointing from a latent variable to an observed variable (i,e.,indicator) indicates the causal effect of the latent variable on the observed variable. The absence of an arrow between two variables indicates an imposed constraint on the model's parameter. For example, in Figure 3.3 the absence of an arrow pointing from ξ_2 to observed indicator x_1 implies that x_1 does

Figure 3.3: Combined Measurement and Structural Model



not measure ξ_2 (i.e., $\lambda_{12} = 0$). Table 3.4 provides a summary of the LISREL model parameters.

3.5.2.1 Model Identification

Identification of the LISREL model must be demonstrated before estimation can proceed. Model identification entails demonstrating that the free (estimated) parameters $\mathbf{\Gamma}$, $\mathbf{\Lambda}_x$, $\mathbf{\Lambda}_y$ in the model have unique estimates. An empirical check on identification is performed using the LISREL computer program.

In general, any LISREL model can not be identified until the metric or scale of the exogenous latent variables ξ and endogenous latent variables η has been established. Since the latent variables are hypothetical, they can be given any scale, but it is common to give them the same scales as the corresponding observed indicators (Hayduk, 1987). Setting the metric is commonly accomplished by setting the loading (i.e, λ) of one of the observed variables on the latent variable equal to a fixed value such as 1. For example, in $x_1=\lambda_1\xi_1+\delta_1$, if loading $\lambda_1=1$, then a one unit change in ξ_1 produces a one unit change in x_1. Since a latent variable's scale is determined by a single fixed loading, it is unnecessary and overly restrictive to fix the loadings of more than one observed variable on any latent variable (Long, 1983a). Another alternative to establishing the scale of a latent variable is to assume that the latent variables are standardized, i.e., that they have unit variances.

Table 3 4. Summary of the LISREL Model Parameters

Matrix	Description	Dimension	Mean	Covariance	Dimension
$\mathbf{y}$	observed endogenous variables	3x1	0	$E(\mathbf{y}\mathbf{y}')$	3x3
$\mathbf{x}$	observed exogenous variables	50x1	0	$E(\mathbf{x}\mathbf{x}')$	50x50
η	latent endogenous variables	1x1	0	$E(\eta\eta')$	1x1
ξ	latent exogenous variables	14x1	0	$\Phi=E(\xi\xi')$	14x14
ζ	errors in structural equation	1x1	0	$\Psi=E(\zeta\zeta')$	1x1
Γ	direct effects of ξ on η	1x14	-	-	-
Λ_x	loadings of $\mathbf{x}$ on ξ	50x14	-	-	-
Λ_y	loadings of $\mathbf{y}$ on η	3x1	-	-	-
δ	measurement errors for $\mathbf{x}$	50x1	0	$\Theta_\delta=E(\delta\delta')$	50x50
ϵ	measurement errors for $\mathbf{y}$	3x1	0	$\Theta_\epsilon=E(\epsilon\epsilon')$	3x3

3.5.2.2 Model Estimation

The LISREL computer program (Joreskog and Sorbom, 1989) is used to estimate the parameters of the proposed model. The estimation procedure is based on comparing the model-based variances and covariances of the observed indicators (which are contained in a matrix defined as $\mathbf{\Sigma}$) to the variances and covariances (or correlations) calculated from the data on the observed indicators (which are contained in a matrix defined as $\mathbf{S}$)

The general objective in estimating the LISREL model is to find estimates of the model parameters (i.e., free coefficients in matrices $\mathbf{\Gamma}$, Λ_x, Λ_y, and covariance matrices $\mathbf{\Phi}$, $\mathbf{\Theta}_\delta$, $\mathbf{\Theta}_\epsilon$, and $\mathbf{\Psi}$) that reproduce the sample matrix $\mathbf{S}$ of variances and covariances (or correlations) of the observed variables as closely as possible, and satisfy the constraints imposed on the model. Estimates are those values of the parameters that minimize the difference (where the difference is defined by the method of estimation, e g., maximum likelihood, generalized least squares, or unweighted least squares) between the observed variance-covariance matrix $\mathbf{S}$ and the predicted variance-covariance matrix $\mathbf{\Sigma}$. The $\mathbf{\Sigma}$ matrix is defined as:

$$\mathbf{\Sigma} = \left[\begin{array}{c:c} E(\mathbf{yy}') & E(\mathbf{yx}') \\ \hdashline E(\mathbf{xy}') & E(\mathbf{xx}') \end{array}\right] \qquad (3.4)$$

Inserting the mathematical forms of the matrices described previously, we can represent $\boldsymbol{\Sigma}$ as (Hayduk, 1987): (See Appendix B for derivation)

$$\boldsymbol{\Sigma} = \left[\begin{array}{c|c} \Lambda_y(\Gamma\Phi\Gamma'+\Psi)\Lambda'_y + \Theta_\epsilon & \Lambda_y\Gamma\Phi\Lambda'_x \\ \hline \Lambda_x\Phi\Gamma'\Lambda'_y & \Lambda_x\Phi\Lambda'_x + \Theta_\delta \end{array}\right] \qquad (3.5)$$

For data input purposes, when the observed variables are all of ordinal type (i.e., responses are classified into different ordered categories), Joreskog and Sorbom recommend that estimates of "polychoric" correlations be provided as **S** instead of the ordinary Pearson product moment correlations. The polychoric correlations are estimated based on the underlying theoretical continuous variables that the ordinal variables approximate. Hayduk (1987) also recommends using the polychoric correlations when the variables originate from poor classification of truly multivariate normal variables. The PRELIS program (Joreskog and Sorbom, 1986) is used to generate the polychoric correlations.

Table 3.5 lists the number of parameters that must be estimated in the model. Matrix $\boldsymbol{\Gamma}$ contains fourteen free parameters; matrix Λ_x contains 50 parameters of which 14 are fixed to 1 to set the scale of each exogenous latent variable, thus making the number of free parameters to be estimated 36; matrix Λ_y contains three parameters, one of which is fixed to 1 to set the scale of the endogenous latent variable, thus leaving 2 free parameters to be estimated; covariance matrix $\mathbf{\Phi}$ contains fourteen free parameters assuming the exogenous latent variables to be uncorrelated; covariance matrix $\mathbf{\theta}_\delta$ contains 50 free parameters assuming the measurement errors in $\mathbf{x}$ to be uncorrelated; covariance matrix $\mathbf{\theta}_\epsilon$ contains three free parameters assuming the measurement errors in $\mathbf{y}$ to be uncorrelated; $\mathbf{\Psi}$ is a free scalar representing the error variance of the structural equation of the model. Note that some of the above fixed covariance terms may be freed, if it makes substantive sense to do so, in order to provide a better fit for the model (see Model Modification section for detail).

Table 3 5. Parameters Estimated in the $\mathbf{\Sigma}$ Matrix

Matrix	No. of Free Parameters
$\mathbf{\Gamma}$	14
$\mathbf{\Lambda}_x$	36
$\mathbf{\Lambda}_y$	2
$\mathbf{\Phi}$	14
$\mathbf{\theta}_\delta$	50
$\mathbf{\theta}_\epsilon$	3
$\mathbf{\Psi}$	1
	Total: 120

Estimates of the parameters that reproduce the sample matrix $\mathbf{S}$ are commonly estimated using the maximum likelihood (ML) method, although other methods for parameter estimation are available (e.g., Generalized Least Squares (GLS) and Unweighted Least Squares (ULS)). The GLS estimation is the second most widely used procedure because it does not assume multivariate normality and it still allows a χ^2 test of model fit. The ULS estimation procedure does not make assumptions about the distribution of the observed variables, but there are no statistical tests associated with ULS estimation (Long, 1983b). Hayduk (1987) recommends estimating a given model using more than one estimation procedure and comparing the results

The ML method, which is used in estimating the parameters in this study, takes as an estimate of a universe parameter the value that maximizes the probability of producing the sample results, (Duncan, 1976). The maximum likelihood method is favored by many statisticians because the estimates it yields have desirable asymptotic properties, that is, properties that hold as the sample size gets large. Long (1983a) describes the following properties of the ML estimates:

1) ML estimates are approximately normally distributed. Such a property allows researchers to test the significance of the estimated parameters using the z-test statistic.

2) ML estimates are efficient in that their sampling distributions have minimum variance.

3) ML estimates are consistent in that the values of the

estimates converge to the true population parameters as the sample size increases.

The ML estimator minimizes the fitting function F defined as (Hayduk, 1987)

$$F_{ML} = tr(\mathbf{S}\mathbf{\Sigma}^{-1}) + \log|\mathbf{\Sigma}| - \log|\mathbf{S}| - (p + q) \qquad (3.6)$$

where

$tr(\mathbf{S}\mathbf{\Sigma}^{-1})$ is the trace of the indicated matrices,

$\log|\mathbf{\Sigma}|$ is the log of the determinant of the matrix $\mathbf{\Sigma}$,

$\log|\mathbf{S}|$ is the log of the determinant of the matrix $\mathbf{S}$,

$(p + q)$ is the number of observed endogenous and exogenous indicators (i.e., 50 exogenous indicators and 3 endogenous indicators for our proposed model).

It should be noted, however, that the mathematical justification for the ML estimation requires assumptions of normality of the observed variables (i.e., the indicators $\mathbf{x}$ and $\mathbf{y}$), although very little is known about the effects of violations of the assumption of normality on the properties of the ML estimators (Long, 1983a). Joreskog and Sorbom (1989), however, warn that the standard errors of the estimates must be interpreted with caution when the normality assumption has been violated. In this study, histograms of the observed variables are plotted to measure the extent of deviation from normality.

3.5.2.3 Assessment of Fit

Assessment of fit is tested for the model as a whole and for the individual estimated parameters. The overall fit of the model is assessed using the ratio of chi-square (χ^2) relative to the degrees of freedom. The chi-square test statistic is defined as: $\chi^2 = nF$, where F is the maximum likelihood function described previously, and n is the sample size minus 1. The degrees of freedom (d.f.) for the χ^2 test are calculated as the difference between the total number of unique (i.e., non-redundant) entries in the observed variance-covariance matrix **S** and the total number of coefficients estimated in the model. Thus, d.f. is defined as (Hayduk, 1987):

$$\text{d.f.} = 1/2\ [(p+q)(p+q+1)] - t \qquad (3.7)$$

where p and q refer to the number of observed endogenous and exogenous indicators, respectively, and t is the total number of estimated coefficients (i.e., d.f. = 1/2 [(53)(54)] - 120] = 1311 for the proposed model). The closer the predicted **Σ** matrix is to the **S** sample matrix, the smaller is the ratio of χ^2 to the degrees of freedom. Wheaton, Blair, Muthen, Alwin, and Summers (1977) suggest that a χ^2 five times the degrees of freedom is acceptable, while Carmines and McIver (1981) suggest that two or three times is more reasonable. Moreover, the coefficient of determination R^2, defined as the percentage of variation in the latent endogenous variable that is explained by the latent exogenous variables, is also reported. The coefficient of determination is defined as:

$$R^2 = 1 - \frac{VAR(\zeta)}{VAR(\eta)} \qquad (3.8)$$

The ML estimated coefficients are tested to check whether they are statistically different from zero, at a desired level of significance, using the z-test statistic. The standard deviations of the sampling distributions of the estimates (used in computing the critical z values) are the square roots of the diagonal elements (i.e., the variances) of the variance-covariance matrix for the estimates.

3.5.2.4 Model Modification

If the model does not fit adequately, one way to improve the fit is to eliminate parameters that are not significantly different from zero, as indicated by a z-test, and to re-estimate the model (Long, 1983a).

Alternatively, to improve the fit of the model, parameters can be added to the model. The LISREL computer program calculates a "modification index" for every fixed parameter in the model. The modification index represents the minimum expected reduction in the χ^2 statistic if a parameter is changed from fixed to free (Breckler, 1990). In using the modification index, it is suggested that the parameter with the largest modification index be relaxed as long as it makes theoretical sense to relax it (Long, 1983a). This procedure continues relaxing one parameter at a time, until an adequate fit is found or no further improvement in fit is possible.

3.5.3 Second-Order Factor Model

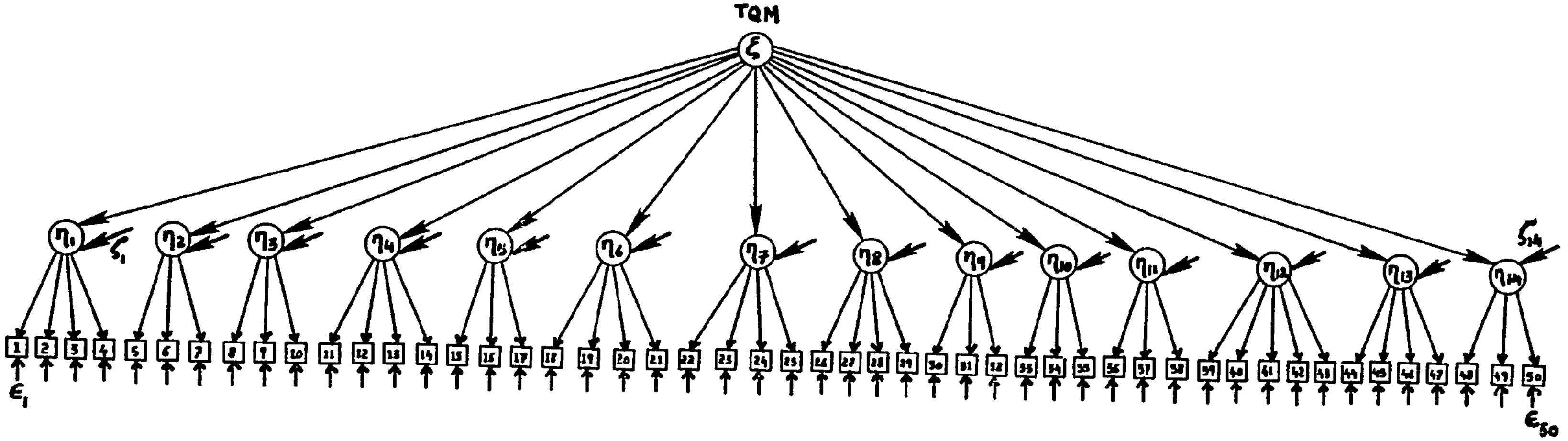
The LISREL computer program is used to test whether there are sufficient relationships among Deming's principles to extract a second-order factor resembling "Total Quality Management" (TQM). The model that is used to test this premise is a "submodel" of the previously described LISREL model. In specific, the second-order factor model consists of two equations:

Structural Equation: $$\underset{(14x1)}{\eta} = \underset{(14x1)}{\Gamma}\ \underset{(1x1)}{\xi} + \underset{(14x1)}{\zeta} \qquad (3.9)$$

Measurement Equation: $$\underset{(50x1)}{\mathbf{y}} = \underset{(50x14)}{\Lambda_y}\ \underset{(14x1)}{\eta} + \underset{(50x1)}{\epsilon} \qquad (3.10)$$

Equation 3.9 represents the structural equation that links Deming's fourteen factors (η above) to TQM (ξ). Equation 3.10 represents the measurement equation that links the observed indicators to their respective hypothesized factors Figure 3.4 illustrates the second-order factor model. First-order factor loadings are given by Λ_y while second-order factor loadings are given by Γ. The parameter matrices applicable to this model are Λ_y, Γ, Φ, Ψ and Θ_ϵ. The procedures used for identifying, estimating and modifying the previously described LISREL model linking Deming's factors to quality performance are also applied to this second-order factor model.

Figure 3.4: Second-Order Factor Model



CHAPTER 4

RESULTS

4.1 Sample Statistics

Table 4.1 shows the relative frequency distributions, and the means of the division managers' responses to the items measuring the degree of implementation of Deming's fourteen principles (see section 3.4.1, pp. 39-41 for each item's definition).

A review of Table 4.1 reveals several interesting observations regarding the degree of implementation of Deming's fourteen factors of quality management. For example, although most hourly employees received training in statistical improvement techniques and in quality related matters (as measured by items X18 and X19, respectively), there were few programs to develop effective communication among employees or to broaden employees' skills for future organizational needs (as measured by X44 through X47). This may reinforce the traditional belief that most U.S. firms plan only for the short run to serve the immediate needs of the organization.

Moreover, pressure for short term results (X42 negatively worded), a deterrent to quality improvement, appeared to plague about 50% of all firms (46.9% of all respondents replied "mostly true" to "completely true" to the item asking

Table 4.1: Relative Frequency Distributions and Means of Managers' Responses to Items Measuring Deming's Fourteen Principles

Item	RESPONSE CATEGORY					Mean
	0	1	2	3	4	
X1	1.2%	9.2%	22.0%	41.6%	26.0%	2.82
X2	4.0%	16.2%	20.2%	23.7%	35.9%	2.71
X3	2.9%	10.4%	34.1%	37.6%	15.0%	2.51
X4	1.2%	15.6%	25.4%	39.9%	17.9%	2.58
X5	1.2%	10.4%	19.6%	38.7%	30.1%	2.86
X6	3.5%	8.7%	17.3%	29.5%	41.0%	2.96
X7	3.5%	12.1%	23.1%	34.1%	27.2%	2.69
X8	3.5%	22.5%	43.4%	28.9%	1.7%	2.03
X9	9.8%	20.8%	35.8%	26.6%	7.0%	2.00
X10	2.3%	6.9%	19.6%	37.7%	33.5%	2.93
X11	2.9%	12.7%	24.8%	42.8%	16.8%	2.58
X12	8.1%	22.6%	46.2%	17.9%	5.2%	1.90
X13	3.5%	6.4%	26.0%	49.1%	15.0%	2.66
X14	4.1%	9.2%	32.4%	43.3%	11.0%	2.48
X15	0.6%	9.2%	26.0%	48.0%	16.2%	2.70
X16	2.3%	12.7%	31.8%	33.5%	19.7%	2.55
X17	4.0%	14.5%	27.2%	36.4%	17.9%	2.50
X18	5.8%	16.2%	17.9%	29.5%	30.6%	2.63
X19	1.7%	13.3%	20.2%	38.2%	26.6%	2.75
X20	4.6%	22.5%	45.7%	27.2%	0.0%	2.95
X21	5.2%	15.0%	17.9%	42.2%	19.7%	2.56
X22	0.6%	6.9%	24.8%	56.1%	11.6%	2.71
X23	2.9%	10.4%	27.2%	48.5%	11.0%	2.54
X24	4.0%	10.4%	32.4%	46.8%	6.4%	2.41
X25	11.0%	26.0%	39.9%	21.4%	1.7%	1.77
X26	1.2%	13.3%	35.8%	39.3%	10.4%	2.45
X27	0.6%	9.2%	20.2%	58.4%	11.6%	2.71
X28	2.9%	5.8%	28.3%	38.1%	24.9%	2.76
X29	3.5%	6.9%	18.5%	27.7%	43.4%	3.01
X30	1.7%	14.5%	35.8%	39.9%	8.1%	2.38
X31	5.2%	15.6%	31.2%	39.9%	8.1%	2.30
X32	5.8%	17.4%	35.8%	38.7%	2.3%	2.14
X33	3.5%	17.9%	31.8%	41.0%	5.8%	2.28
X34	13.9%	22.0%	31.2%	26.6%	6.3%	1.90
X35	15.6%	20.2%	24.9%	22.5%	16.8%	2.05
X36	2.3%	15.0%	26.6%	46.8%	9.3%	2.46
X37	20.8%	27.8%	32.9%	16.8%	1.7%	1.51
X38	3.5%	15.6%	23.7%	31.8%	25.4%	2.60
X39	24.8%	24.3%	18.5%	13.9%	18.5%	1.77
X40	1.1%	2.9%	13.9%	34.7%	47.4%	3.24
X41	5.8%	17.9%	32.4%	26.6%	17.3%	2.32
X42	16.8%	30.1%	25.4%	23.1%	4.6%	1.69
X43	2.9%	8.1%	20.8%	30.6%	37.6%	2.92
X44	11.0%	21.4%	27.7%	29.5%	10.4%	2.07
X45	13.9%	27.8%	28.3%	22.5%	7.5%	1.82
X46	23.1%	29.5%	25.4%	16.8%	5.2%	1.51
X47	12.7%	27.7%	29.5%	21.4%	8.7%	1.86
X48	2.3%	11.0%	15.0%	42.2%	29.5%	2.86
X49	2.9%	12.7%	20.2%	39.3%	24.9%	2.71
X50	7.5%	14.5%	24.8%	34.1%	19.1%	2.43

whether there is pressure for short term results). The results further suggests that "management by numbers" is still a practice that is exercised in U.S. firms. For example, 42.8% of all respondents replied "somewhat true" to "completely true" to the item asking whether numerical quotas are given higher priority than quality of workmanship (X38 negatively worded).

Moreover, although top management appeared to be active towards executing its quality improvement policies (71.7% of all respondents replied "mostly true" to "completely true" to item X48), the degree of reliance on using internal or external consultants to implement such policies was only moderate (53.2% of all respondents replied "mostly true" to completely true" to item X50). Furthermore, 67.6% of all managers responded "somewhat true" to "completely true" to the item asking whether performance appraisals are used to rank employees (X39 negatively worded), in contrast to Deming's teachings which stress that performance appraisals build fear and undermine teamwork.

4.2 Normality Assessment

The purpose of this section is to evaluate the extent to which the observed variables deviate from normality. As described in section 3.5.2, maximum likelihood estimation of the LISREL parameters assumes that the variables have a multivariate normal distribution in the population.

To test this assumption of normality, histograms were constructed for each observed variable to see how well they approximate the normal probability distribution (see Appendix C) It should be noted that even if the marginal distributions of the variables are normally distributed, this still does not guarantee that the variables have a multivariate normal distribution in the population.

A visual inspection of the histograms shows that some cases are approximately normally distributed, while others are negatively skewed (e.g., X2, X5, X6, X18). A negatively skewed distribution has most of its cases concentrated at the high end of the measuring scale (Levin, 1981).

If the distribution of the observed variables are moderately non-normal or skewed, the ML estimates can still be used to fit the LISREL model to the data. Specifically, the estimated parameters remain consistent regardless whether the ML, GLS, or ULS estimation procedures are used (Bollen, 1989). That is, as the sample size grows larger, the estimated LISREL parameters converge to the true population values even for non-normal distributions. However, Joreskog and Sorbom (1989) warn that standard errors and chi-square values output by LISREL must be interpreted with caution when the normality assumption has been violated. Cuttance (1987) asserts that standard errors may be underestimated when the data are skewed, while Bentler and Chou (1987) report that the chi-square statistic may be unreliable when assumptions regarding distributions are not met.

Although distribution-free estimation procedures for estimating the LISREL model are available, Bentler and Chou (1987) claim that such procedures become computationally impractical with models having more than 20-30 variables. Furthermore, their statistics tend to be questionable with sample sizes less that 200.

The next sections describe the procedures that are used to measure the internal consistency of the scales (reliability), the appropriateness of each item in each scale (item analysis), and the extent to which the survey items measure what they are intended to measure (validity).

4.3 Assessing the Homogeneity of Responses of Division Managers and Hourly Employees

To investigate how the managers' responses compare with the hourly employees in a given division, 11 divisions from different organizations were selected and one hourly employee from each division completed the questionnaire. The correlation coefficient (r) was used to measure the association between the two sets of responses (i.e., the division managers and the hourly employees). Table 4.2 shows that the degree of correlation between the responses ranges from 0.11 (weak association) to 0.73 (strong association) with a mean value of 0.48.

Table 4.2: Degree of Correlation Between Responses of Division Managers and Hourly Employees

Division No.	Correlation Coefficient (r)
1	0.40
2	0.11
3	0.58
4	0.60
5	0.43
6	0.46
7	0.28
8	0.46
9	0.65
10	0.73
11	0.58
	Mean: 0.48

The above results reveal that, overall, there is some degree of correlation between the two sets of responses. However, one potential weakness with the above approach is its inability to pinpoint where the agreements or disagreements lie between the managers' and the hourly employees' responses to the survey questions. The chi-square test of homogeneity was used to assess whether the responses from the hourly employees and the managers were homogeneous with respect to each survey question. If the degrees of freedom (defined as the product of the number of response categories minus 1 and the number of groups tested [i.e., managers and hourly employees] minus 1) are less than 30 and if the minimum expected frequency is at least 2, Cochran (1952) states that the use of the chi-square test is adequate. Adjacent response categories may be combined to achieve the minimum expected cell frequencies.

The following represents a sample computation to test the hypothesis whether managers and hourly employees are homogeneous with respect to their responses to item X1 (top management makes long term plans). Table 4.3 shows the observed and the expected frequencies (shown in parentheses) in each category for item X1. In this table, anchors 0 and 1 were combined into one category (1), anchors 2 and 3 were combined into another category (2), while anchor 4 was treated as a separate category (3). This re-classification scheme was done in order to achieve a minimum expected frequency of 2 per cell. If the two sampled populations (i.e., managers and hourly employees) are homogeneous with respect to their response in each category, the best estimate of the true proportion of subjects selecting category 1 in each group is given by 5/22 = 0.2273. To find the expected frequency for category 1 in each group, each sample total is multiplied by 0.2273. Thus, (11)(0.2273)=2.5. Similar computations were conducted to estimate the expected frequencies in categories 2 and 3. Thus, the appropriate hypothesis are:

H0: The two groups are homogeneous with respect to their responses in each category

H1: The two groups are not homogeneous with respect to their responses in each category

From the data in Table 4.3, we may compute

$$X^2 = (2-2.5)^2/2.5+(3-2.5)^2/2.5+(6-5)^2/5+(4-5)^2/5$$
$$+(3-3.5)^2/3.5+(4-3.5)^2/3.5 = 0.74$$

Table 4.3: Observed and (Expected) Frequencies for Item X1

Group	Category 1	Category 2	Category 3	Total
Managers	2(2.5)	6(5)	3(3.5)	11
Employees	3(2.5)	4(5)	4(3.5)	11
Total	5	10	7	22

The critical value of χ^2 for $\alpha = 0.05$ and 4 degrees of freedom is 9.49. Since the computed value, 0.74, is smaller than 9.49, we accept the null hypothesis that the two populations have homogeneous responses. Table 4.4 shows the variable number, the categories that were grouped in order to have an expected frequency of at least 2 per cell, the degrees of freedom (df), the computed X^2, critical χ^2 value at the 0.05 significance level, and whether the two groups have homogeneous responses.

As depicted in Table 4.4, the results show that the two groups were homogeneous with respect to their responses to all survey questions with the exception of variables X11 (supplier selection is based on both quality and price rather than price alone), X27 (employees seek their supervisors' assistance when unsure of their tasks), X28 (employees are not afraid to report working conditions that interfere with quality), X46 (there are programs to develop employees' conflict resolution skills), X47 (there are programs to broaden employees' skills for future organizational needs), and X48 (top management executes its quality improvement policies).

Table 4.4 Homogeneity Results of Survey Measures

Variable	Category Grouped	df	Computed X^2	Critical χ^2	Homogeneous
X1	(1,2) (3,4) (5)	2	0.74	5.99	YES
X2	(1,2) (3) (4,5)	2	2.62	5.99	YES
X3	(1,2) (3) (4,5)	2	1.00	5.99	YES
X4	(1,2,3) (4) (5)	2	0.00	5.99	YES
X5	(1,2,3,4) (5)	1	0.21	3.84	YES
X6	(1) (2) (3,4,5)	2	0.00	5.99	YES
X7	(1,2,3) (4) (5)	2	2.06	5.99	YES
X8	(1,2,3) (4,5)	1	0.79	3.84	YES
X9	(1,2) (3) (4,5)	2	1.07	5.99	YES
X10	(1,2,3) (4) (5)	2	1.70	5.99	YES
X11	**(1,2,3) (4) (5)**	**2**	**6.89**	**5.99**	**NO**
X12	(1,2) (3) (4,5)	2	0.00	5.99	YES
X13	(1,2,3) (4) (5)	2	0.29	5.99	YES
X14	(1,2,3) (4,5)	1	1.89	3.84	YES
X15	(1,2,3) (4) (5)	2	0.90	5.99	YES
X16	(1,2,3) (4,5)	1	0.18	3.84	YES
X17	(1,2,3) (4) (5)	2	0.18	5.99	YES
X18	(1) (2) (3,4,5)	2	3.33	5.99	YES
X19	(1,2,3,4) (5)	1	0.73	3.84	YES
X20	(1,2,3) (4) (5)	2	1.17	5.99	YES
X21	(1,2,3) (4) (5)	2	5.33	5.99	YES
X22	(1,2,3) (4) (5)	2	0.96	5.99	YES
X23	(1,2,3) (4,5)	1	1.64	3.84	YES
X24	(1,2,3) (4,5)	1	1.64	3.84	YES
X25	(1,2) (3,4,5)	1	0.73	3.84	YES
X26	(1,2,3) (4,5)	1	0.19	3.84	YES
X27	**(1,2,3) (4,5)**	**1**	**6.25**	**3.84**	**NO**
X28	**(1,2,3) (4) (5)**	**2**	**8.47**	**5.99**	**NO**
X29	(1) (2,3,4,5)	1	0.73	3.84	YES
X30	(1,2,3) (4,5)	1	0.21	3.84	YES
X31	(1,2) (3) (4,5)	2	0.00	5.99	YES
X32	(1,2) (3) (4,5)	2	2.49	5.99	YES
X33	(1,2) (3) (4,5)	2	1.28	5.99	YES
X34	(1,2) (3) (4,5)	2	3.43	5.99	YES
X35	(1) (2,3) (4,5)	2	0.90	5.99	YES
X36	(1,2,3) (4,5)	1	0.00	3.84	YES
X37	(1,2) (3) (4,5)	2	0.96	5.99	YES
X38	(1) (2) (3) (4,5)	3	1.34	7.81	YES
X39	(1) (2,3,4) (5)	2	0.00	5.99	YES
X40	(1) (2,3,4,5)	1	0.73	3.84	YES
X41	(1) (2,3) (4,5)	2	0.31	5.99	YES
X42	(1,2) (3) (4,5)	2	1.96	5.99	YES
X43	(1) (2) (3,4,5)	2	0.31	5.99	YES
X44	(1,2) (3) (4,5)	2	1.17	5.99	YES
X45	(1,2) (3) (4,5)	2	0.00	5.99	YES
X46	**(1) (2) (3,4,5)**	**2**	**8.21**	**5.99**	**NO**
X47	**(1) (2) (3) (4) (5)**	**4**	**15.8**	**9.49**	**NO**
X48	**(1) (2) (3,4,5)**	**2**	**9.00**	**5.99**	**NO**
X49	(1,2,3) (4) (5)	2	0.92	5.99	YES
X50	(1,2,3) (4) (5)	2	3.14	5.99	YES
X51	(1,2,3) (4,5)	1	0.73	3.84	YES
X52	(1,2,3) (4) (5)	2	1.23	5.99	YES
X53	(1,2) (3,4,5)	1	3.14	3.84	YES
X54	(1,2) (3,4,5)	1	0.79	3.84	YES
X55	(1,2,3) (4,5)	1	0.73	3.84	YES
X56	(1,2,3) (4) (5)	2	1.33	5.99	YES

Although the sample size that was used in comparing the two sets of responses was rather small, the homogeneity results, nevertheless, show that selecting division managers as a "proxy" for hourly employees' responses was a good choice. In particular, the results show that of all the questions that pertained to hourly employees, there were disagreements on only two items (i.e., X27 and X28).

4.4 Reliability

Reliability is the consistency of measurement (Bollen, 1989). There are four methods commonly used to measure reliability. (1) the test-retest method, (2) the parallel forms method, (3) the split-half method, and (4) the internal consistency method (Flynn, Sakakibara, Schroeder, Bates, and Flynn, 1990).

In the test-retest method, the same questionnaire is given to a group of individuals at two different points in time. The correlation coefficient obtained from correlating the two scores is then used to measure reliability.

In the parallel forms method, two equivalent and alternative forms of the same instrument are administered to the same subjects at two different points in time. The correlation between the scores is known as the parallel forms reliability estimate.

The test-retest and the parallel form methods require two administrations using the same group of subjects. In contrast, the split-half method requires one administration only. Specifically, to measure the reliability of a scale (e.g., a hypothesized Deming factor), its indicators (i.e., the items used to measure the concept) are split into two subsets. The sum is then computed for each subset and the correlation of the two subsets is used as an estimate of reliability. However, one disadvantage of this method is that there are many different combinations in which a given set of items can be divided into two halves, thus yielding different reliability estimates for each split.

The internal consistency method overcomes this disadvantage by incorporating every possible split of the scale in its calculation. Cronbach's alpha (Cronbach, 1951), commonly used to estimate a scale's internal consistency, is expressed as (Carmines and Zeller, 1979):

$$\text{ALPHA} = [(\text{N})(\text{AVGCOV})/(\text{AVGVAR})]/[1 + (\text{N} - 1)(\text{AVGCOV})/(\text{AVGVAR})] \tag{4 1}$$

where N is the number of items used to measure a concept, AVGCOV is the average covariance between items, and AVGVAR is the average variance of the items. If the items are standardized to have a variance of 1, the above formula can be simplified to:

$$\text{ALPHA (Standardized)} = (\text{N})(\text{AVGCOR})/[1 + (\text{N} - 1)(\text{AVGCOR})] \tag{4 2}$$

where AVGCOR represents the arithmetic average of the off-diagonal elements (i.e., the upper diagonal or lower diagonal elements) of the correlation matrix. If the items comprising a given scale have fairly comparable variances, there is little difference between the standardized and unstandardized alphas. Moreover, it is assumed that the items comprising a scale are positively correlated with each other because they are measuring, to a certain extent, a common concept. Nunnally (1967) suggests that an alpha value of 0.60 is generally acceptable for newly developed scales.

In this study, Cronbach's standardized alpha was used to assess the internal consistency of the instruments used to measure Deming's 14 principles and the quality performance of the firm. It must be emphasized, however, that the internal consistency, as measured by alpha, refers to the degree of inter-relatedness among the items that constitutes a scale. Thus, for a given scale or factor, if many companies are implementing certain practices more than other practices for the same factor, the degree of inter-relatedness among the practices (measured by AVGCOR) would be low, which would in turn drive the value of alpha down.

The SPSS reliability program (Norusis, 1990) was used to assess the reliability of all scales. Table 4.5 summarizes the reliability analysis results, while Appendix D provides more detailed information concerning inter-item correlations, means, variances, etc. (see section 3.4, for items' definitions).

The results in Table 4.5 show that four of Deming's factors (3, 10, 12, & 14) had an alpha value below the minimum threshold of 0.60. This indicates that the degree of inter-relatedness among the items comprising each of the above four factors to be moderately low (i.e., within a given factor, certain practices are implemented more than others).

The low internal consistency of factor 3 (ceasing dependence on mass inspection) may be attributed to the low correlation coefficient (.17, see Appendix D, p. 162) between items "top management supports the belief that quality must be built into the product and not inspected into it" (variable X10) and "suppliers use statistical control techniques" (variable X8).

Table 4.5 Internal Consistency Analysis of Deming's Factors

Scale (Factor)	Cronbach's Alpha (Standardized)
1 Creating constancy of purpose	0.69
2 Adopting the new philosophy	0.72
3 Ceasing dependence on mass inspection	0.55
4 Ending the practice of awarding business on price tag only	0.76
5 Constantly improving the system	0.67
6 Instituting training	0.61
7 Instituting leadership	0.86
8 Driving out fear	0.63
9. Breaking down barriers between departments	0.76
10 Eliminating slogans & exhortations	0.38
11 Eliminating numerical quotas	0.60
12. Removing barriers to pride in workmanship	0.43
13. Instituting education	0.84
14. Taking action to accomplish the transformation	0.58
15 Quality performance	0.63

This low correlation is observed because although top management supports building quality into the product, there is perhaps less control over forcing their suppliers to use statistical control techniques. In particular, as Table 4.1 depicts, 71.2% of all respondents replied "mostly true" to "completely true" to variable X10 (top management supports the belief that quality must be "built into" the product and not "inspected into" it), while only 30.6% of all respondents replied "mostly true" to "completely true" to variable X8 (suppliers use statistical quality control techniques).

The low internal consistency of factor 10 (eliminating slogans & exhortations) is attributed to the low mean of the inter-item correlations (0 17). The correlation coefficient between variables X34 (top management, not the hourly worker, takes responsibility to removing obstacles that cause defects) and X35 (top management does not use vague slogans [e.g., "do it right the first time"] in communicating with its employees) was 0.01, thus dropping the overall mean of the inter-item correlations. The mean of variable X34 was 1.90, thus indicating perhaps in the mind of the respondents that there is a shared responsibility between top management and hourly employees to removing obstacles that cause defects, rather than putting all the responsibility on top management alone. The reliability analysis results indicate that Cronbach's alpha would increase to 0.52 with the deletion of variable X34 from the scale.

The low internal consistency of factor 12 (removing barriers to pride in workmanship) may be caused by the variety in content of the indicators (as defined by Deming) that were used to operationalize this factor. The respondents' answers varied considerably among the indicators, resulting in low internal consistency. For example, 11.0% of all respondents replied "mostly true" to "completely true" to the item asking whether top management sets unrealistic goals for its employees (X43), 46.9% of all respondents replied "mostly true" to "completely true" to the item asking whether there is pressure for short term results (X42), 4.0% of all respondents replied "mostly true" to "completely true" to the item asking whether the quality of the working environment is poor (X40), and 49.1% replied "mostly true" to "completely true" to the item asking whether performance appraisals are used to rank employees (X39). However, the reliability analysis results indicate that Cronbach's alpha would increase to 0.51 with the deletion of the item asking whether performance appraisals are used to rank employees (X39).

The low internal consistency of factor 14 resulted from item X50 (top management uses internal or external consultants to implement its quality improvement policies) correlating poorly with items X48 (top management executes its quality improvement policies) and X49 (top management makes its quality improvement policies visible to all employees) yielding correlation coefficients of 0.23 and 0.29, respectively. This weak association arises because although top management is found to be active towards executing its quality improvement policies (71.7% of all respondents replied "mostly true" to "completely true" to this item), the degree of reliance on using internal or external consultants to implement such policies is only moderate (53.2% of all respondents replied "mostly true" to "completely true" to this item). Cronbach's alpha is not improved if any of the items comprising this scale are deleted.

4.5 Item Analysis

This method, developed by Nunnally (1967), evaluates the correlation of each measurement item with each scale (i.e., Deming factor). The scale of each factor is obtained by computing the arithmetic average of the scores of the items that comprise that scale. Table 4.6 shows the correlation of each item with each scale. The correlation matrix shows the items to correlate highly with the scales they intend to measure (shown in bold in Table 4.6), thus suggesting that the items had been appropriately assigned to scales. For example, as depicted in Table 4.6, because scale 1 (creating constancy of purpose) is the average of items 1 to 4, the high correlation between scale 1 and these four items (i.e., X1, X2, X3, and X4) comprising this scale was expected. Correlations between scales are examined in section 4.6.3.2 using confirmatory factor analysis to learn more about the inter-relationships among Deming's fourteen principles.

Table 4.6· Correlations Between Survey Items and Scales

Item	Scales													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1	**.70**	.56	.34	.14	.43	.31	.36	.35	.32	.31	.33	.32	.32	.42
X2	**.72**	.24	.28	.10	.21	.19	.23	.16	.16	.21	.24	.28	.11	.27
X3	**.78**	.32	.32	.09	.32	.18	.33	.24	.25	.37	.20	.26	.28	.31
X4	**.67**	.46	.33	.15	.36	.35	.32	.26	.35	.44	.22	.27	.52	.36
X5	.52	**.81**	.39	.13	.48	.31	.34	.32	.36	.34	.33	.26	.29	.55
X6	.25	**.73**	.34	.20	.27	.20	.28	.27	.36	.21	.34	.27	.21	.42
X7	.55	**.86**	.47	.21	.45	.37	.37	.36	.47	.46	.46	.34	.41	.60
X8	.18	.13	**.65**	.60	.38	.34	.19	.29	.26	.04	.32	.17	.21	.23
X9	.30	.32	**.81**	.35	.35	.46	.28	.32	.31	.15	.45	.02	27	.39
X10	.48	.61	**.72**	.25	.46	.37	.40	.37	.46	.52	.50	.40	.38	.54
X11	.23	.29	.50	**.80**	.28	.33	.20	.26	.30	.15	.30	.21	.33	.26
X12	.12	.14	.40	**.75**	.20	.20	.11	.22	.22	.06	.22	.16	.18	.18
X13	.11	.26	.44	**.84**	.32	38	.23	.28	.24	.06	.31	.12	.20	.30
X14	.05	.02	.28	**.67**	.08	.12	.11	.15	.09	.07	.16	.03	.11	.07
X15	.31	.33	43	32	**.78**	.34	.30	.31	.39	.20	.41	.15	.38	.38
X16	.40	.47	.54	.26	**.84**	.32	.43	.39	.56	.33	.49	.28	.46	.46
X17	.32	.33	.30	.11	**.70**	.25	.28	.24	.19	.28	.21	.06	.14	.26
X18	.17	.25	.41	.27	.17	**.73**	.12	.29	.18	.18	.30	.19	.13	.25
X19	.34	.34	.42	.23	.37	**.74**	.35	.42	.25	.29	.40	.07	.32	.37
X20	.32	.22	.16	.16	.30	**.46**	.34	.33	.31	.30	.18	.18	.23	.28
X21	19	.19	.44	.27	.23	**.78**	.28	.34	.23	.16	.30	.02	.14	.26
X22	.40	.36	.35	.17	.39	.36	**.75**	.41	.41	.43	.37	.30	.26	.38
X23	.38	.40	.32	.17	.40	.33	**.90**	.53	.46	.32	.43	.29	.31	.37
X24	.38	.32	.35	.16	.35	.34	**.85**	.36	.38	.31	.38	.18	.27	.39
X25	30	.32	.34	.21	34	.26	**.84**	.44	.40	.34	.44	.28	.31	.33
X26	.35	.35	.37	.32	.38	.35	.37	**.70**	.40	.14	.40	.36	.29	.35
X27	.28	.32	35	.14	.20	.28	.52	**.64**	.32	.25	.32	.23	.17	.31
X28	17	26	.31	.23	.30	.34	.37	**.76**	.33	.15	.39	.23	.18	.25
X29	17	.17	.21	.13	.23	.36	.21	**.63**	.20	.15	.31	.17	.08	.35
X30	.31	41	42	.21	.43	.22	.34	.33	**.77**	.21	.51	.25	.34	.37
X31	.34	.51	.44	.30	.46	.34	.41	.43	**.87**	.37	.50	.38	.43	.48
X32	.26	.30	.32	.17	.32	.28	.46	.34	**.83**	.29	.40	.30	.37	.35
X33	51	36	.43	.18	.37	.42	.46	.40	.35	**.69**	.31	.28	.44	.44
X34	.04	.13	.08	.07	.08	.15	.14	.06	.15	**.57**	.10	.02	.09	.15
X35	.39	.36	.21	.00	.28	.12	.26	.09	.23	**.73**	.15	.39	.29	.27
X36	.37	.38	.49	.29	.42	.37	.42	.39	.50	.26	**.78**	.41	.25	.40
X37	.04	.21	.43	.22	.33	.31	.22	.35	.30	.10	**.69**	.10	.19	.32
X38	37	.45	.40	.22	.32	.30	.43	.42	.47	.24	**.77**	.44	.28	.42
X39	.05	.12	.03	.01	.15	.10	.07	.01	.04	.02	.04	**.49**	.01	.11
X40	.36	.31	.18	.15	.21	.17	.37	.29	.33	.26	.27	**.45**	.29	.29
X41	.32	.33	.10	.02	.12	.11	.18	.13	.25	.17	.27	**.54**	.12	.27
X42	.34	.41	.34	.17	.35	.22	.34	.43	.45	.24	.49	**.68**	.22	.37
X43	21	19	.19	.14	.13	.12	.15	.22	.15	.35	.27	**.58**	.07	.27
X44	.37	.35	.38	.18	.39	.29	.30	.18	.41	.37	.27	.13	**.88**	.33
X45	.35	.32	.32	.26	.35	.25	.28	.21	.45	.35	.32	.29	**.83**	.37
X46	.17	.18	.24	.20	.25	.14	.20	.21	.27	.20	.22	.07	**.83**	.21
X47	.49	.39	.37	.24	.38	.26	.36	.24	.40	.39	.26	.24	**.76**	.34
X48	.33	.56	.42	.14	.34	.26	.31	.36	.40	.44	.43	.41	.26	**.73**
X49	.42	.58	.50	.26	.47	.44	.42	.46	.44	.35	.45	.26	.38	**.76**
X50	.29	.32	.29	.18	.25	.22	.24	.21	.25	.14	.26	.13	.19	**.72**

4.6 Validity

The purpose of validity is to evaluate whether the items measure what they are intended to measure. Content validity, criterion validity, and construct validity are three methods commonly used for this purpose.

4.6.1 Content Validity

The purpose of content validity is to evaluate whether the questions asked are appropriate to the content area claimed for the scales or constructs (Turner and Martin, 1984). Content validity can not be evaluated numerically but can only be determined by experts and by reference to the literature (Flynn, Sakakibara, Schroeder, Bates, and Flynn, 1990). Based on the exhaustive literature review of the Deming philosophy (Deming, 1986, 1982; Walton, 1986; Gitlow, 1990; Gabor, 1990; Aguayo, 1990), and based upon detailed evaluations by academicians and pretest subjects, the content of each factor appears to be adequately represented by the measurement items employed

4.6.2 Criterion Validity

The purpose of criterion validity is to examine the extent to which the observed measures are associated with a criterion measure (Dillon, Madden, and Firtle, 1987). Bollen (1989) defines criterion validity as the degree of correspondence between a measure and a criterion variable, commonly measured by their correlation. For example, in the context of the scales that were developed to measure Deming's factors, one expects to find such measures (collectively) to be positively related to the quality performance of the firm. The scale value of quality performance (Q) was obtained by summing its three hypothesized indicators (i.e. customers' retention rate compared to the competition, the features of the products/services compared to the competition, and the frequency of repeating work because it was not done correctly the first time).

Criterion validity was assessed empirically using regression analysis. As a precaution to avoid model misspecification, it was necessary to control for the effects of other variables (i.e. ,advertising/promotion expenditures relative to the competition (A), breadth of the product line relative to the competition (B), and the degree of product/service standardization to reduce defects or errors (S)) that could influence quality, in order to isolate the effect of Deming's philosophy on quality performance. The rationale behind selecting these covariates was outlined in section 3.4.3.

Several regression models were hypothesized in determining the criterion validity of Deming's scales. In some models, the individual effects of Deming's principles on quality performance are examined, while in other models, the collective influence (i.e., all of Deming's principles taken as a group) of the Deming philosophy on quality performance is tested. The purpose behind this approach was to test the premise, which is advocated by Deming, that all the fourteen factors must be implemented in concert in order to achieve better quality performance. The following section describes the different hypothesized models, along with their estimated coefficients and goodness of fit statistics.

The first hypothesized regression model tests the impact of the individual Deming factors on quality performance. This model can be mathematically represented as:

$$Q = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 S + \beta_4 F1 + \beta_5 F2 + \ldots \ldots + \beta_{17} F14 + \epsilon \qquad (4.3)$$

In this model, F1, F2, ..., F14 (Deming's fourteen principles) were formed by summing the items hypothesized to comprise each factor. The estimated model yielded the following results (t-values in parenthesis):

$$\begin{array}{llllllll}
Q = 5.84 & -\ 02A & +\ .13B & +\ .17S & +\ .01F1 & +\ .04F2 & +\ 12F3 & -.01F4 \\
\quad \mathbf{(8.65)} & (-\ 18) & (1.06) & (1.36) & (\ 29) & (.79) & (1.65) & (-\ 31) \\
 & & & & & & & \\
-\ 03F5 & -\ .06F6 & +\ 07F7 & +\ .09F8 & +\ .16F9 & +\ .03F10 & +\ .41F11 & \\
\quad (-.53) & (-.13) & (1.53) & (1.74) & \mathbf{(2.60)} & (.61) & (.64) & \\
 & & & & & & & \\
+\ 00F12 & +\ 10F13 & -\ 05F14 & & & & & \\
\quad (.02) & \mathbf{(3.16)} & (-.85) & & & & &
\end{array} \qquad (4.4)$$

The coefficient of determination R^2 was 0.48, while R^2_a (R^2 adjusted for the number of independent variables in the model) was 0.43. The above results indicate that the fit of this hypothesized model was inadequate. In specific, many independent variables were statistically insignificant, including the control variables (i.e., A, B, and S), while other variables (e.g., F4, F5, F6, and F14) had the wrong sign. However, factor 9 (breaking down barriers between departments), factor 13 (instituting education), and the constant term were significant. The observed residuals were approximately normally distributed and had a constant variance, thus indicating that no potential violations of least squares assumptions were present.

The second hypothesized regression model tests the impact of the individual Deming factors on quality performance, assuming interactions among the items comprising each factor. This model can be mathematically represented as:

$$Q = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 S + \beta_4 F1 + \beta_5 F2 + \dots + \beta_{17} F14 + \epsilon \tag{4.5}$$

In this model, the variables F1, F2,......, F14 were formed by multiplying the items that constituted each scale. For example, for each subject, the variable F1 was formed by multiplying the values of the responses of its four indicators (i.e., $F1_i = X1_i * X2_i * X3_i * X4_i$, for subject i). This scale assumes interactions among all the items that comprise each factor. That is, it is assumed that the effect of different practices that form a given Deming factor are inter-dependent. The estimated model yielded the following results:

$$\begin{aligned} Q = {} & \underset{(\mathbf{14.55})}{7.88} + \underset{(.07)}{01A} + \underset{(1\ 28)}{17B} + \underset{(1.88)}{.25S} - \underset{(-.36)}{.00F1} + \underset{(\mathbf{2.02})}{.01F2} + \underset{(.62)}{.01F3} + \underset{(1.22)}{.00F4} \\ & - \underset{(-.79)}{01F5} - \underset{(-\ 66)}{00F6} + \underset{(1.28)}{.00F7} + \underset{(1\ 47)}{00F8} + \underset{(\mathbf{3.29})}{04F9} + \underset{(1.67)}{.02F10} + \underset{(.15)}{.00F11} \\ & + \underset{(\ 29)}{00F12} + \underset{(\mathbf{2.12})}{01F13} - \underset{(-.84)}{.00F14} \end{aligned} \tag{4.6}$$

The value of the coefficient of determination R^2 was 0.45, and the value of R^2_a was 0.39. The overall fit of this model appeared to be worse (as measured by R^2 or R^2_a) than the previous model, thus perhaps suggesting that the effects of items within a scale may not be inter-dependent. As in model (4.4), the coefficients of factor 9 (breaking down barriers between departments), factor 13 (instituting education), and the constant term were significant, while the other independent variables, including the covariates, were insignificant Potential violations underlying least squares regression were not found.

One possible disadvantage associated with the previously hypothesized models arises from isolating the individual effects of Deming's principles on quality performance, rather than examining the cumulative effect of the Deming philosophy as a whole. Thus, the third hypothesized regression model introduces a "Deming" variable which measures the additive influence of <u>all</u> Deming's practices.

$$Q = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 S + \beta_4 \text{Deming} + \epsilon \qquad (4.7)$$

In this model, the Deming variable was formed by summing the respondents' scores on all 50 items measuring Deming's fourteen factors[1]. The estimated coefficients were:

---

[1] Thus, model (4.7) is equivalent to model (4.3) estimated subject to the linear equality constraint $\beta_4=\beta_5=....=\beta_{17}$, and hence, must yield a lower R^2 than model (4.3).

$$Q = \underset{\mathbf{(8.12)}}{4.97} - \underset{(-.08)}{0.01A} + \underset{(1.25)}{0.15B} + \underset{(.97)}{0.12S} + \underset{\mathbf{(7.96)}}{0.04Deming} \qquad (4.8)$$

The coefficients of determination, measured by R^2 and R^2_a, were 0.41 and 0.40, respectively. Moreover, the Deming variable and the constant term were the only statistically significant variables[2]. Although R^2 was not very high, nevertheless, the results indicate that 41% of the total variation in quality performance has been explained by the model. Upon regressing quality performance against the Deming variable only (including the constant term), 40% of the total variation in quality performance was explained by the Deming variable.

The fourth regression model investigated the impact of the Deming philosophy on quality performance assuming interactions among the factors. In other words, this model assumes that all of Deming's principles must be implemented in concert with each other. Specifically, this model can be mathematically represented as:

$$Q = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 S + \beta_4 Deming + \epsilon \qquad (4.9)$$

where the variable Deming = F1*F2*F3*.....*F14, and each factor is formed by summing the items which measure that factor (e.g., F1=X1+X2+X3+X4, F2=X5+X6+X7, etc.). Thus, this model assumes that the effects of the fourteen factors are inter-dependent while all items measuring each factor

---

[2] The mean of the variable "Deming" was 121.5, while its range was [62,178]. The mean of the variable "Q" was 10.7, while its range was [7,15].

independently contribute to that factor. The estimated model generated the following results:

$$\begin{array}{lllllllllll} Q = & 8.26 & + & 2.5E\text{-}03A & + & 0.17B & + & 0.54S & + & 1.54E\text{-}15Deming^{[3]} & (4.10) \\ & \mathbf{(14.04)} & & (0.02) & & (1.21) & & \mathbf{(4.41)} & & \mathbf{(3.37)} & \end{array}$$

Although the variables S and Deming were statistically significant, the overall fit of the model, however, was poor (R^2=0.24, R^2_a=0.22). This perhaps suggests that the hypothesized multiplicative nature of the factors may not be appropriate.

To test the impact of the multiplicative effects of Deming's principles on quality performance, controlling for additive effects, the following model was investigated:

$$Q = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 S + \beta_4 DemingA + \beta_4 DemingA + \epsilon \qquad (4.11)$$

In this model, the variable "DemingA", which represents the additive effects of Deming's principles, was formed by summing the respondents' scores on all 50 items measuring Deming's fourteen factors. The variable "DemingM", which represents the multiplicative effects of Deming's principles, was formed by multiplying the fourteen factors (i.e., DemingM = F1*F2*...*F14, where F1=X1+X2+X3+X4, F2=X5+X6+X7, etc.). The estimated model generated the following results:

$$\begin{array}{lllllllllllll} Q = & 5.03 & - & 0.01A & + & 0.12S & + & 0.15B & + & 0.04DemingA & + & 8.63E\text{-}17DemingM & (4.12) \\ & \mathbf{(7.23)} & & (-0.10) & & (0.97) & & (1.22) & & \mathbf{(6.96)} & & (0.19) & \end{array}$$

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[3] The mean of the variable "Deming" was 9.1×10^{13}, while its range was $[0, 2.3 \times 10^{15}]$.

The coefficients of determination, measured by R^2 and R^2_a, were 0.41 and 0.40, respectively. Moreover, the variable "DemingA" and the constant term were the only statistically significant variables. The results show that the multiplicative effects of Deming's principles have no impact on quality performance, when the additive effects of Deming's principles are held constant

Based upon the results of the previously hypothesized regression models, one may conclude that many of Deming's factors have weak or no impact on the hypothesized quality performance measures. However, one possible cause for this "dampening" effect may be attributed to the sample selection procedure. Specifically, many of the surveyed firms were committed to quality improvement programs, and this may have resulted in reducing the variance of the variables. For example, as illustrated by the histograms in Appendix C, many variables were negatively skewed, which is indicative of firms' devotion to quality programs. Moreover, in all the hypothesized regression models, the constant term was highly significant which may be another indication of the bias component associated with using the PACE sample. Thus, in future research, a control sample (i.e., a sample consisting of firms that may not be totally committed to quality) should be included to be able capture the effect of the Deming philosophy on quality performance.

Furthermore, the results showed that the models which hypothesized the additive influence of Deming's factors (i.e., models (4.3) and (4.7)) demonstrated greater criterion validity than the models that assumed multiplicative forms (i.e., models (4.5) and (4.9)). In fact, model (4.11) which accounts for both additive and multiplicative effects of Deming's factors reveals that Deming's principles have an impact on quality performance even when not used in concert with each other. In other words, the multiplicative theory that suggests that <u>all</u> of Deming's principles <u>must</u> be rigorously applied is not supported.

4.6.3 Construct Validity

The purpose of construct validity is to evaluate whether a scale is an appropriate operational definition of an abstract variable (Flynn, Sakakibara, Schroeder, Bates, and Flynn, 1990). Bollen (1989) defines the construct validity of a measure x_i of a latent variable ξ_j as the significance of the direct structural relation between x_i and ξ_j measured by the structural coefficient (or loading) λ_{ij}. In this study, the LISREL VII computer program (Joreskog and Sorbom, 1989) was used to assess the construct validity of Deming's fourteen factors and the quality performance scale. The polychoric correlations of the observed variables used as the sample correlation matrix **S** input to the LISREL program are provided in Appendix E in the same order as the survey questions.

4.6.3.1 Assessing the Construct Validity of the Individual Scales

Each factor was examined individually to test the statistical significance of the loadings of the observed measures on the associated hypothesized latent variable. As a rule of thumb, factor loadings with z-values below 2.0 are considered insignificant. Table 4.7 shows the maximum likelihood estimates of the factor loadings and their corresponding z-statistics. The latent variables were standardized (i.e., they have unit variances) in order to define their scales.

The results shown in Table 4.7 illustrate that the indicators of factor 10 ("eliminating slogans and exhortations") had insignificant loadings. Moreover, $\lambda_{39,12}$ ("performance appraisals are used to rank employees") did not load significantly on its hypothesized factor "removing barriers to pride in workmanship". All other indicators, however, significantly loaded on their hypothesized factors.

4.6.3.2 Confirmatory Factor Analysis

Next, Deming's factors and their observed indicators (excluding the insignificant loadings, i.e., factor 10 and $\lambda_{39,12}$, and the quality performance scale since this factor is not part of Deming's measurement model) were analyzed collectively to investigate relationships or inter-dependence among the factors.

Table 4.7. Factor Loading Estimates

Parameter	Estimate	Z-Value
$\lambda_{1,1}$	0.56	6.97
$\lambda_{2,1}$	0.62	7.72
$\lambda_{3,1}$	0.87	10.67
$\lambda_{4,1}$	0.47	5.75
$\lambda_{5,2}$	0.78	10.16
$\lambda_{6,2}$	0.54	7.02
$\lambda_{7,2}$	0.93	12.10
$\lambda_{8,3}$	0.40	3.95
$\lambda_{9,3}$	0.94	5.35
$\lambda_{10,3}$	0.45	4.19
$\lambda_{11,4}$	0.72	10.15
$\lambda_{12,4}$	0.61	8.31
$\lambda_{13,4}$	0.92	13.68
$\lambda_{14,4}$	0.63	8.57
$\lambda_{15,5}$	0.74	7.70
$\lambda_{16,5}$	0.98	9.04
$\lambda_{17,5}$	0.36	4.38
$\lambda_{18,6}$	0.61	7.36
$\lambda_{19,6}$	0.60	7.27
$\lambda_{20,6}$	0.29	3.38
$\lambda_{21,6}$	0.82	9.48
$\lambda_{22,7}$	0.70	10.34
$\lambda_{23,7}$	0.96	16.40
$\lambda_{24,7}$	0.85	13.57
$\lambda_{25,7}$	0.79	12.27
$\lambda_{26,8}$	0.68	8.27
$\lambda_{27,8}$	0.62	7.59
$\lambda_{28,8}$	0.76	9.16
$\lambda_{29,8}$	0.38	4.49
$\lambda_{30,9}$	0.64	8.56
$\lambda_{31,9}$	0.88	12.13
$\lambda_{32,9}$	0.78	10.68
$\lambda_{33,10}$	**1.88**	**0.49**
$\lambda_{34,10}$	**0.08**	**0.44**
$\lambda_{35,10}$	**0.22**	**0.48**
$\lambda_{36,11}$	0.90	7.28
$\lambda_{37,11}$	0.43	4.84
$\lambda_{38,11}$	0.58	5.89
$\lambda_{39,12}$	**0.04**	**0.51**
$\lambda_{40,12}$	0.30	3.38
$\lambda_{41,12}$	0.32	3.74
$\lambda_{42,12}$	0.99	6.06
$\lambda_{43,12}$	0.41	4.25
$\lambda_{44,13}$	0.92	14.85
$\lambda_{45,13}$	0.79	11.93
$\lambda_{46,13}$	0.81	12.34
$\lambda_{47,13}$	0.64	8.94
$\lambda_{48,14}$	0.61	5.85
$\lambda_{49,14}$	0.76	6.54
$\lambda_{50,14}$	0.45	4.84
λ_{Q1}	0.79	8.21
λ_{Q2}	0.69	7.52
λ_{Q3}	0.50	5.90

Note λ_{Q1}, λ_{Q2}, and λ_{Q3} are the quality performance loadings, that correspond, respectively, to items 51, 52, and 55 of the survey instrument

The modification indices (MI), (which represent the minimum reduction in the χ^2 statistic if a constrained parameter is freed) generated by the LISREL VII program were used as a guide in this search process. This procedure involves relaxing, one at a time, the parameter with the largest modification index (as long as it makes substantive sense to do so) until an adequate fit is found. Specifically, once the parameter with the largest MI is relaxed, the LISREL model is re-estimated, a new set of MI's are computed, and the next variable with the highest MI is identified. The ratio of χ^2 to the degrees of freedom (χ^2/df) is used in assessing the adequacy of fit. Wheaton, Blair, Muthen, Alwin, and Summers (1977) suggest that a χ^2 five times the degrees of freedom is acceptable, while Carmines and McIver (1981) suggest that two or three times is more reasonable.

The orthogonal model (i.e., the initial model constraining the factors to be uncorrelated) resulted in a χ^2/df ratio of 4.18. The values of the estimated parameters for the orthogonal model were the same as the values presented in Table 4.7 due to the imposed constraints on the orthogonal model (i.e., not allowing Deming's factors to be interrelated). Table 4.8 shows the order in which the constrained parameters were freed to improve the fit of the model, the modification indices of the constrained parameters, and the resulting improvement in the model's fit as measured by the χ^2/df statistic.

Table 4.8: Model Improvement Resulting from Freeing Constrained Parameters

Iteration No	Parameter Freed	MI	χ^2	df	χ^2/df
1	$\Phi_{14,2}$	89.3	4007.7	988	4.06
2	$\lambda_{10,2}$	64.2	3908.1	987	3.96
3	$\Phi_{9,5}$	60.8	3831.7	986	3.89
4	$\Phi_{8,7}$	58.8	3753.8	985	3.81
5	$\Phi_{6,3}$	49.8	3692.5	984	3.75
6	$\Phi_{11,12}$	40.8	3622.8	983	3.69
7	$\lambda_{8,4}$	34.8	3562.2	982	3.60
8	$\lambda_{1,2}$	34.5	3507.8	981	3.58
9	$\lambda_{4,13}$	34.4	3465.4	980	3.54
10	$\lambda_{47,1}$	19.5	3441.6	979	3.51
11	$\lambda_{19,2}$	19.1	3417.0	978	3.49

As depicted in Table 4.8, the highest reported modification index (89.30) was associated with parameter $\Phi_{14,2}$, thus revealing that factor 14 ("taking action to accomplishing the transformation") and factor 2 ("adopting the new philosophy") are correlated. This indicates that management's commitment to quality may be demonstrated by its actions towards executing its quality improvement policies. After re-estimating the model, X10 "top management supports the belief that quality must be <u>built into</u> the product and not <u>inspected into</u> it" (which is an indicator of factor 3) loaded significantly on factor 2 "adopting the new philosophy". Thus, it was appropriate to relax parameter $\lambda_{10,2}$ since management's endorsement of building quality into its product is a valid indicator of its commitment to quality improvement.

Upon relaxing $\lambda_{10,2}$ and re-estimating the model, parameter $\Phi_{9,5}$ had the largest modification index indicating that factor 9 "breaking down barriers between departments " and factor 5 "constantly improving the system of production or service" are correlated. It is reasonable to find such an association since incorporating customers' requirements into the design of the product or service to improve quality is a process that involves interaction among different departments such as finance, design and engineering, production, distribution, and marketing.

Next, factor 7 "instituting leadership" correlated with factor 8 "driving out fear", yielding a MI of 58.8. This relationship demonstrates that supervisors' leadership plays an important role in driving out fear among employees. For example, when supervisors build the trust of their employees and help them on the job, the quality of the working environment should improve.

After $\Phi_{8,7}$ was relaxed, the association between factor 6 "instituting training" and factor 3 "ceasing reliance on mass inspection" yielded the largest modification index. This inter-dependence is justifiable since training employees in statistical quality improvement techniques is a prerequisite to minimizing reliance on mass inspection.

Factor 11 "eliminating numerical quotas" and factor 12 "removing barriers to pride in workmanship" were also interrelated. Such an association stems from the fact that numerical quotas and work standards based on quality (rather than quantity alone) are instrumental in providing the employees with a sense of pride in their workmanship.

Variable X8 "suppliers use statistical quality control techniques" also loaded on factor 4 "ending the practice of awarding business based on price tag alone". This linkage is sensible because supplier selection should, among other factors, be based on providing statistical evidence of the quality of incoming parts.

Variable X1 "top management makes long term plans" also loaded on factor 2 "adopting the new philosophy". This loading is reasonable because long term plans made by top management should, according to Deming, incorporate strategies aimed at improving quality.

Furthermore, variable X4 "top management promotes employee training/education" loaded on factor 13 "instituting education and self-improvement". This relationship is a logical one since promoting employees' training and education is an essential component to the process of instituting education and self-improvement.

Variable X47 "there are programs to develop employees' skills for future needs" loaded on factor 1 "creating constancy of purpose". This relationship is a sound one because by developing its employees' skills for future organizational needs, top management is investing in the long term survival of the organization.

Also, variable X19 "employees are trained in quality related matters" loaded on factor 2 "adopting the new philosophy". This relationship illustrates the importance of training as a vital component to management's commitment to continuous quality improvement.

Factor 11 "eliminating numerical quotas" correlated with factor 3 "ceasing dependence on mass inspection", yielding a maximum MI value of 19.0. However, the strategy of freeing this constrained parameter was not pursued because of two reasons (1) the improvement in the model's overall fit would only be minor (i.e., the value of the χ^2/df statistic would decrease to 3.48, which is only a 0.01 reduction from the last iteration), (2) the number of estimated parameters relative to our sample size would considerably grow, thus increasing the chances of nonconvergence. Computational problems during optimization (e.g., non-convergence of the iterative procedure, or negative error variance estimates) were found to be an inverse function of sample size (e.g., Anderson and Gerbing, 1984; Boomsma, 1985; Gerbing and Anderson, 1987; MacCallum, 1986). Although strict guidelines for minimum sample sizes do not exist, Bentler (1985) suggests that a sample size to number of parameters ratio of 5:1 is sufficient, as a rule of thumb, to achieve reliable estimates in maximum likelihood estimation, while a ratio of 10:1 may be more appropriate for arbitrary distributions. Boomsma (1987) suggests that at least 200 observations are sufficient as a general rule, but provides no information regarding the reliability of this rule as the number of estimated parameters increases. The sample size used in this study (173) approaches Boosma's recommendation.

Figure 4.1 illustrates the resulting measurement model along with the relaxed parameters that are represented by the broken lines. The values of the estimated parameters along with their corresponding significant z-values are shown in Table 4.9

To summarize, the previous results show that the instruments of factor 3, 10, 12, and 14 fail the reliability tests. Such findings demonstrate the lack of homogeneity among the items comprising each of these factors. Moreover, the construct validity of factor 10, and item X39 (which was used as an instrument of factor 12) was not supported. This suggests that the items used to measure these factors are not measuring what they are intended to measure.

The confirmatory factor analysis results provide several insights about Deming's fourteen factors. First, some of the factors are correlated, a finding that suggests that some of Deming's principles are inter-dependent. This association may symbolize the collective importance of the factors claimed by

Figure 4.1: Confirmatory Factor Analysis Model

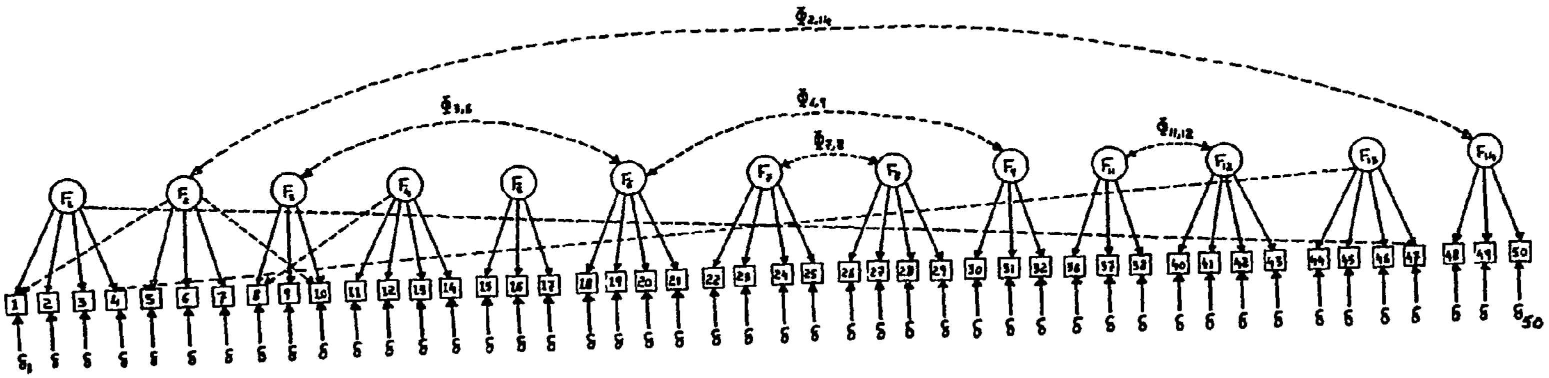

Table 4.9: Final Estimates of the Confirmatory Factor Analysis Model

Parameter	Estimate	Z-Value	Parameter	Estimate	Z-Value
λ1,1	0.27	4.19	λ26,8	0.64	8.42
λ2,1	0.62	7.49	λ27,8	0.72	9.61
λ3,1	0.89	10.21	λ28,8	0.68	9.04
λ4,1	0.33	4.61	λ29,8	0.36	4.41
λ47,1	0.33	5.06	λ30,9	0.68	9.41
λ1,2	0.54	8.32	λ31,9	0.88	13.12
λ5,2	0.79	11.96	λ32,9	0.76	10.83
λ6,2	0.56	7.68	λ36,11	0.73	9.48
λ7,2	0.92	15.14	λ37,11	0.40	4.84
λ10,2	0.70	10.49	λ38,11	0.74	9.65
λ19,2	0.35	5.40	λ40,12	0.42	5.03
λ8,3	0.21	3.10	λ41,12	0.41	4.84
λ9,3	0.76	6.57	λ42,12	0.76	9.47
λ10,3	0.23	3.54	λ43,12	0.47	5.75
λ8,4	0.63	9.21	λ4,13	0.47	6.76
λ11,4	0.79	11.47	λ44,13	0.90	14.54
λ12,4	0.74	10.56	λ45,13	0.80	12.08
λ13,4	0.80	11.73	λ46,13	0.81	12.34
λ14,4	0.56	7.42	λ47,13	0.59	9.01
λ15,5	0.73	10.19	λ48,14	0.64	8.68
λ16,5	0.98	14.48	λ49,14	0.74	10.09
λ17,5	0.35	4.64	λ50,14	0.42	5.37
λ18,6	0.63	7.93	Φ2,14	0.95	21.77
λ19,6	0.47	6.61	Φ3,6	0.75	7.01
λ20,6	0.24	2.86	Φ5,9	0.67	11.67
λ21,6	0.84	10.76	Φ7,8	0.74	14.08
λ22,7	0.71	10.46	Φ11,12	0.87	12.78
λ23,7	0.97	16.94			
λ24,7	0.84	13.29			
λ25,7	0.79	12.14			

the constituency of Deming's Total Quality Management philosophy.

Second, the items (i.e., practices) that loaded on more than one factor (i.e., X1, X4, X8, X19, and X47) do not diminish the construct validity of their hypothesized respective factors. Rather, such findings suggest that these practices contribute towards more than one factor. For example, although variable X4 "top management promotes employee training/education" is hypothesized to be an indicator of factor 1 "creating constancy of purpose", it is reasonable to assume that top management's promotion of training and education is a critical ingredient of "instituting education and self-improvement" (i.e., factor 13)

4.7 Principal Components Analysis

An exploratory principal component factor analysis was conducted to determine whether the observed correlations among the items measuring Deming's fourteen factors can be explained by the existence of a smaller number of hypothetical factors. The reasons behind this approach were twofold: 1) to reduce Deming's fourteen factors to a smaller size in order to decrease the number of estimated parameters in the model, and thus increase the ratio of the sample size to the number of estimated parameters. This approach decreases the chances of running into computational problems arising from using a small sample size; and 2) to determine whether the empirical data on observable quality-inducing efforts of the firms falls along the totality or only a subset of Deming (or "Deming-like") principles.

The mathematical procedure that is used in this "exploratory" factor analysis is conceptually similar to that used in confirmatory factor analysis with one key difference. In the confirmatory factor model, the observed variables are constrained to be affected by specific latent variables that are specified by the researcher based upon a prior theoretical model. However, in the exploratory factor analysis, beyond the specifications of the number of factors and observed variables to be analyzed, the researcher does not specify the structure of the relationships among the variables in the model. That is, all observed variables are assumed to be directly affected by all factors.

There are three basic steps in applying exploratory factor analysis: (1) generating the correlation matrix among the observed variables, (2) extracting the factors that account for as much variance as possible in the data, and (3) transforming (or rotating) the factors to make them more interpretable.

The SPSS factor program (Norusis, 1990) was used in executing the above three steps. Only factors that accounted for variances greater than one (i.e., eigenvalues greater than one) were extracted. The rationale behind this approach is that factors with a variance less than one are no better than a single variable, since every variable was standardized and has a variance of 1.

Based upon this criterion, fourteen factors were extracted that accounted for 67.4% of the total variation in the observed variables. Table 4.10 contains the final estimates from the principal components analysis. As depicted in Table 4.10, the proportion of the variance of an observed variable explained by all extracted factors is called the "communality" of the variable. For example, the fourteen extracted factors account for 58% of the variance of variable

Table 4 10 Principal Components Statistics

VARIABLE	COMMUNALITY	FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
X1	.57881	1	12.79594	25.6	25 6
X2	.70715	2	3.02273	6.0	31 6
X3	.67771	3	2.32607	4.7	36 3
X4	.62456	4	2.08072	4.2	40.5
X5	.71765	5	1.87623	3.8	44.2
X6	.72285	6	1.67681	3.4	47.6
X7	.75268	7	1 55215	3.1	50.7
X8	.71654	8	1.38445	2.8	53.4
X9	.70660	9	1.35232	2.7	56.1
X10	.73771	10	1.23704	2 5	58.6
X11	.72002	11	1.17500	2.3	61.0
X12	60646	12	1.13061	2.3	63 2
X13	76349	13	1 07556	2.2	65 4
X14	.67683	14	1.02648	2.1	67 4
X15	.68709				
X16	.71659				
X17	69468				
X18	72222				
X19	62795				
X20	.70272				
X21	.69799				
X22	.63234				
X23	80932				
X24	75778				
X25	71970				
X26	.62282				
X27	.61010				
X28	.69940				
X29	60967				
X30	59976				
X31	.67263				
X32	.72482				
X33	.64608				
X34	.70716				
X35	66115				
X36	57390				
X37	56760				
X38	.62224				
X39	.55511				
X40	.62251				
X41	70269				
X42	61610				
X43	.73168				
X44	.79507				
X45	.70685				
X46	.78893				
X47	63925				
X48	69880				
X49	.57540				
X50	.48494				

X1. The total variance explained by each factor is listed in the column labeled "EIGENVALUE".

Table 4.11 contains the "factor pattern" matrix which contains the factor loadings between each transformed (i.e., rotated) factor and each variable. Factors with large coefficients (in absolute value) for a variable are closely related to the variable. Specifically, when the estimated factors are uncorrelated with each other (i.e., orthogonal), the factor loadings are also the correlations between the factors and the variables.

The "VARIMAX" rotation method (an algorithm that minimizes the number of variables that have high loadings on the orthogonal factors) was used in transforming the variables in order to enhance their interpretability[4]. To identify (i.e., interpret) the factors, it is necessary to group the variables that have large loadings on the same factors. One strategy is to sort (in descending order) the matrix of factor loadings so that variables with high loadings on the same factor appear together. Thus, as depicted in Table 4 11, only factor loadings greater than or equal to 0.5 in absolute value (i.e., the "strong" loadings) were considered in order to simplify the interpretation process (Norusis, 1990).

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[4] The "Oblique" rotation method, which assumes interactions among the factors, loaded on the same items as the "VARIMAX" method.

Table 4.11 Rotated (Varimax) Factor Matrix

Item	Extracted Factors													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X7	**.70**	09	25	.21	.04	10	.18	.08	.01	.05	.18	.17	.15	.09
X5	**.69**	.11	12	.16	.01	.04	.19	-.07	.12	.18	.26	.14	-.03	.10
X6	**.66**	.23	.02	.16	.15	09	-.18	.06	-.00	04	-.15	-.25	-.05	.21
X48	**.58**	.14	.12	.22	.01	.13	.02	.47	.08	-.05	-.04	-.15	.03	.02
X10	**.55**	.18	.18	.32	.10	13	.25	.19	-.04	-.13	.14	.11	.26	-.15
X1	**.53**	.17	19	.06	.05	03	.21	.03	.20	.08	.24	.19	-.14	15
X49	45	.21	.24	.22	.13	.20	.02	.18	.03	.24	.15	.20	.06	09
X23	.17	**.81**	.12	.17	.02	03	.06	.07	.19	.05	.10	.12	.00	.04
X25	.10	**.78**	.16	.19	11	-.02	.04	09	.11	.02	.00	.06	.01	- 08
X24	.09	**.76**	.11	.13	07	10	.17	08	.16	.19	.04	-.15	-.05	- 03
X27	.15	**.65**	.04	08	06	17	.05	-.00	-.17	-.02	- 00	.23	.07	.19
X22	.16	**.61**	.09	.19	.02	14	.19	.00	.08	- 10	.23	.11	.21	.08
X46	02	10	**.84**	.08	.09	- 01	-.11	.05	-.08	05	-.08	.12	-.08	- 08
X44	.14	10	**.82**	22	04	13	.07	- 06	03	.03	.00	-.04	-.03	-.10
X45	13	06	**.75**	.27	15	- 01	.03	05	.13	- 03	-.04	-.00	.02	.09
X47	.18	19	**.65**	07	.14	02	.20	- 02	.13	01	.14	-.04	.14	.17
X4	30	06	.49	01	.03	15	.19	04	.29	- 03	.27	.09	.12	.20
X33	.16	26	41	04	00	19	.33	31	15	04	.22	.20	17	-.03
X30	.19	12	.17	**.69**	.07	.01	.09	- 06	05	06	.05	.13	07	.02
X32	.06	33	.18	**.60**	02	.09	-.05	- 03	34	- 10	-.05	-.07	20	.19
X31	.27	.20	26	**.60**	.16	14	-.04	.05	.15	- 09	.06	-.03	04	.23
X16	20	21	.29	**.59**	16	05	.09	.13	-.01	15	.31	-.09	- 12	-.01
X36	.15	16	.05	**.58**	17	.15	.23	.18	08	01	-.00	.20	02	.05
X15	.12	05	.26	.47	25	06	.01	.16	17	.29	.32	-.06	- 26	- 11
X38	.39	24	.06	45	05	06	16	.21	.04	- 08	-.20	.28	-.06	- 05
X42	.22	20	.05	43	11	-.05	.12	.31	- 06	-.08	.07	.22	- 15	.37
X37	-.01	16	.08	42	.16	29	-.10	18	- 30	.33	.01	.04	08	.08
X13	.15	09	03	.10	**.81**	12	-.07	06	11	16	-.01	.04	.05	-.08
X12	- 01	02	09	10	**.74**	07	.06	02	- 06	-.09	.09	.06	- 01	10
X11	22	05	19	09	**.73**	17	.02	- 01	.16	-.16	-.01	-.01	-.12	- 02
X8	- 10	10	09	21	**.68**	26	.04	.06	-.13	- 02	.22	-.07	-.12	14
X14	- 04	04	.03	- 01	**.63**	-.09	.11	.05	.04	17	-.18	.19	.36	- 17
X21	06	16	02	.10	.15	**.76**	.05	-.09	.10	06	.09	12	04	- 09
X18	14	00	.03	.05	.20	**.75**	.02	.23	-.06	- 14	-.03	-.08	- 01	.11
X19	.13	14	.24	08	06	**.50**	.12	.05	.09	25	.20	35	12	07
X9	.22	14	.15	30	.24	.48	.24	-.07	-.17	.23	-.08	06	- 11	-.27
X2	.08	10	-.01	.11	05	.10	**.79**	.06	.10	.05	-.07	-.03	-.02	.15
X3	.17	22	.19	05	.02	- 01	**.69**	.06	.02	- 04	.25	-.01	- 13	.07
X43	17	03	-.01	.09	10	-.11	.17	**.77**	-.02	- 18	- 02	.08	.13	.03
X29	- 00	.12	.00	.08	.03	.34	-.07	**.62**	.20	.19	.04	.06	- 05	.03
X20	.03	16	.12	.10	.06	.08	.03	.17	**.74**	.16	.17	.05	05	.03
X40	.23	.23	15	.18	.04	-.08	.20	-.01	**.59**	-.09	-.17	.16	- 07	-.03
X39	- 06	-.02	- 02	02	.08	.01	.02	.04	-.05	**-.73**	-.10	-.03	-.05	.00
X50	23	.14	04	.14	14	.10	.32	00	.07	.46	-.08	-.16	.03	10
X35	35	14	.25	.07	-.10	-.03	.26	.27	11	- 41	.22	-.26	-.05	-.04
X17	.23	15	-.01	.10	.08	.07	06	-.01	.03	05	**.76**	.07	.08	- 07
X28	.12	.30	.04	.22	11	.16	-.15	.10	.21	- 02	.07	**.65**	-.06	-.02
X26	17	28	.15	.21	.27	.11	.04	.13	.03	.02	.08	.40	-.31	28
X34	06	.10	.05	.06	.01	.05	-.10	.07	.01	.07	.08	-.06	**.81**	05
X41	21	.05	.03	.15	-.01	-.01	21	01	.02	.08	-.07	.00	.05	**.76**

Table 4.12 provides a list of each item's definition that "strongly" loaded (i.e., a loading greater than or equal to 0.5) on its associated factor. As depicted in Table 4.12, the first eight extracted factors (EF's) are meaningful and they may be interpreted, respectively, as top management commitment, instituting supervisory leadership, instituting education, cross-functional communication to improve quality, supplier management, instituting training, innovation, and providing assurance to employees. However, factors EF9 through EF14 were not clear enough to be meaningfully interpreted. Specifically, factors EF10 through EF14 "strongly" loaded on single items which makes the interpretation process difficult.

It should be noted, however, that factors 1 through 8, which were extracted from the exploratory factor analysis procedure closely resemble many of Deming's actual factors. In other words, the items that comprise the extracted factors are similar to (or common with) the items that were hypothesized for Deming's actual factors. For example, factor EF1 resembles Deming's second factor (adopting the new philosophy), factor EF2 resembles Deming's seventh factor (instituting leadership), factor EF3 resembles Deming's thirteenth factor (instituting education and self-improvement), factor EF4 resembles Deming's ninth factor (breaking down barriers between departments), factor EF5 resembles Deming's fourth factor (ending the practice of

Table 4.12: Items Strongly Loading on Extracted Factors

EF1	X7 :	top management is committed to continuous quality enhancement as a primary goal
	X5 :	top management is committed to quality improvement as a way to increase profits
	X6 :	top management is committed to setting objectives for quality improvement
	X48.	top management takes action towards executing its quality improvement policies
	X10:	top management supports the belief that quality must be "built into" the product and not "inspected iinto" it
	X1 .	top management makes long term plans
EF2	X23:	supervisors work to build the trust of their employees
	X25:	supervisors are viewed as coaches by their employees
	X24:	supervisors lead in a way that is consistent with the aims of the organization
	X27:	employees seek their supervisors' assistance when unsure of their tasks
	X22	supervisors help their employees on the job
EF3	X46:	there are programs to develop employees' conflict resolution skills
	X44:	there are programs to develop team-work between employees
	X45:	there are programs to develop effective communications between employees
	X47	there are programs to broaden employees' skills for future organizational needs
EF4	X30:	different departments have compatible goals
	X32:	there is good communications between different departments
	X31:	in the product/service design, there is teamwork between different departments
	X16:	customers' feedback is used to continually improve the product/service
	X36:	work standards are based on quality and quantity rather than quantity alone

Table 4.12 (continued):

EF5	X13:	long-term relationships are developed with suppliers
	X12:	suppliers are involved in the product/service development process
	X11:	supplier selection is based on both quality and price rather than price alone
	X8 :	suppliers use statistical quality control techniques
	X14:	there is reliance on a few dependable suppliers
EF6	X21:	supervisors are trained in statistical improvement techniques
	X18:	employees are trained in statistical improvement techniques
	X19	employees are trained in quality-related matters
EF7	X2 :	top management provides for research and development
	X3 ·	top management provides for new technology
EF8	X43·	top management sets realistic goals for its employees
	X29:	employees feel they have job security
EF9	X20:	employees are trained in specific work-related skills
	X40	the quality of the working environment is good
EF10	X39:	performance appraisals not are used to rank employees
EF11	X17:	top management assesses its competitors in order to improve the product/service
EF12	X28:	employees are not afraid to report working conditions that interfere with quality
EF13	X34:	top management, not the hourly worker, is responsible for removing obstacles that cause defects/errors
EF14	X41:	there is adequate documentation on how to do the job

awarding business based on price tag alone), factor EF6 resembles Deming's sixth factor (instituting training), factor EF7 resembles Deming's first factor (creating constancy of purpose), while factor EF8 resembles Deming's eighth factor (driving out fear).

Interestingly, Deming's extracted factors closely resembled some of the factors that were developed by Saraph, Benson, and Schroeder (1989). For example, EF1 (top management commitment) paralles their first factor "role of divisional top management and quality policy". EF6 (instituting training) resembles their third factor "training". EF4 (cross-functional communications to improve quality) parallels their fourth factor "product/service design". In fact, some of the items that they used in operationalizing this factor (e.g., "coordination among affected departments in the product/service development process", and "extent of analysis of customer requirements in product/service development process") were very similar to the items that were used to measure EF4 (e.g., "in the product/service design, there is teamwork between different departments", and "customers' feedback is used to continually improve the product/sewrvice"). EF5 (supplier management) closely resembles their fifth factor "supplier quality management". EF2 (instituting supervisory leadership) <u>and</u> EF8 (providing assurance to employees) parallels their eighth factor "employee relations".

In subsequent analyses, the first eight extracted factors with the "strong" loadings items will be referred to as "Deming's extracted factors", while their corresponding actual Deming's factors (i.e., factors 1, 2, 4, 6, 7, 8, 9, and 13) will be referred to as "Deming's factors".

4.8 Second-Order Factor Analysis

Using the information that was derived from the exploratory factor analysis, the LISREL VII program (Joreskog and Sorbom, 1989) was used to test whether either set of factors (i e., "Deming's factors" or "Deming's extracted factors") form an overall concept that resembles "Deming's Total Quality Management philosophy". Figure 4.2 shows the path diagram for the second-order factor model using "Deming's extracted factors"[5]. The order in which the factors and their indicators y1, y2,...,y32 are represented in Figure 4.2 is consistent with the order of extraction shown in Table 4.12. As depicted in Figure 4.2, the second-order factor analysis model consists of a structural and a measurement equation which can be mathematically represented as:

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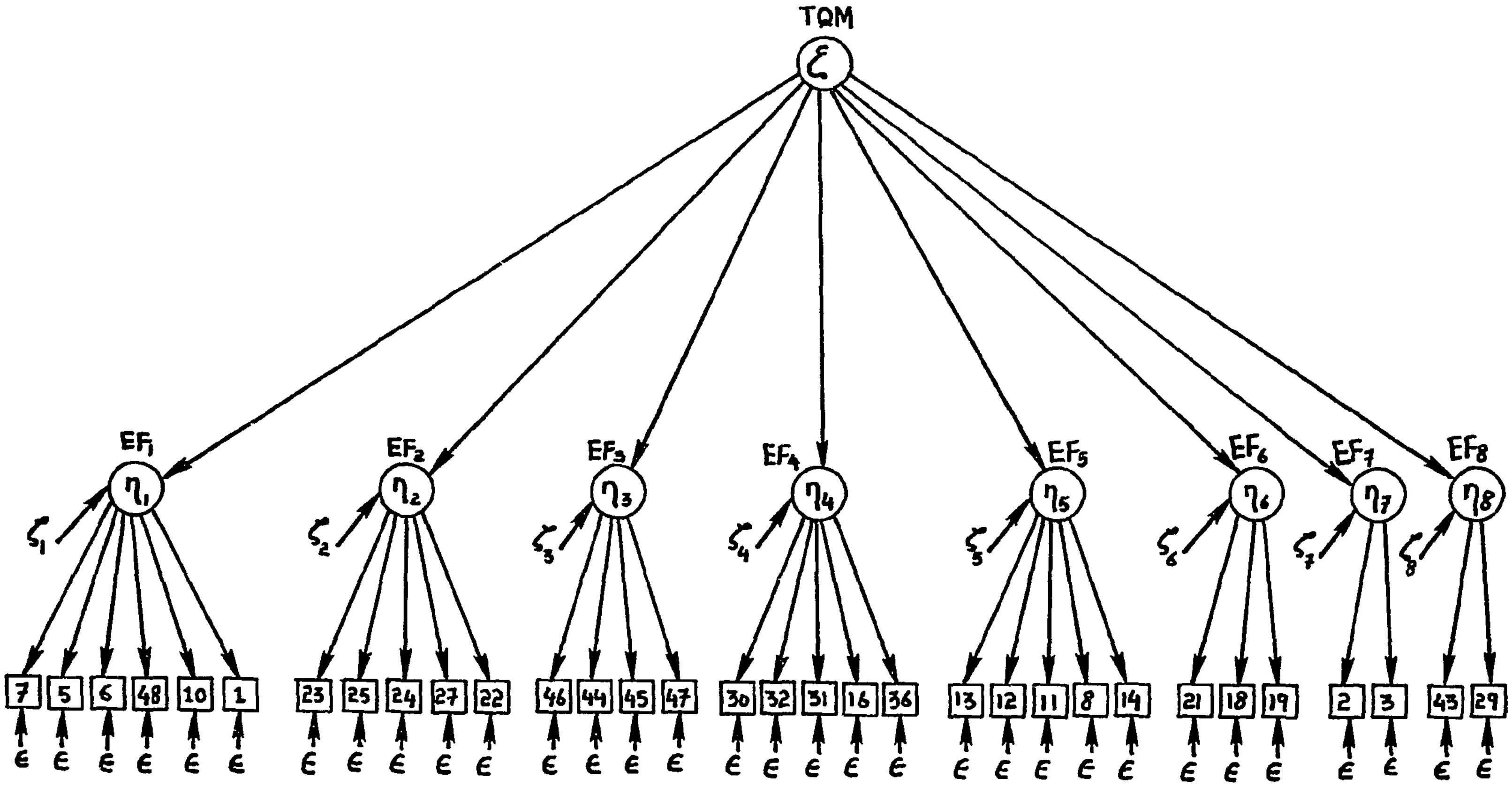
[5] In Figure 4.2, ξ (i.e., TQM) is treated as an exogeneous latent variable with the directions of loadings between TQM and the factors η_1 (i.e., the EF's treated as endogeneous latent variables) being from TQM to η_1.

Figure 4.2: Second-Order Factor Model Using a Subset of Deming's Extracted Factors



Structural equation: $$\underset{(8x1)}{\eta} = \underset{(8x1)}{\Gamma} \quad \underset{(1x1)}{\xi} + \underset{(8x1)}{\zeta} \tag{4.13}$$

Measurement equation: $$\underset{(32x1)}{y} = \underset{(32x8)}{\Lambda_y} \quad \underset{(8x1)}{\eta} + \underset{(32x1)}{\epsilon} \tag{4.14}$$

Table 4.13 contains the maximum likelihood LISREL estimates of the model's parameters and their z-values. All estimated parameters (i.e., the structural coefficients contained in Γ and the measurement coefficients contained in Λ_y) were positive and significant at the 0.05 level. Moreover, the overall goodness of fit of the model measured by the ratio of χ^2/df was 2.71 (1235.33/456), thus, suggesting that the proposed model fits the data reasonably well. That is, Deming's extracted factors appear to constitute an overall construct that may be interpreted as some "TQM philosophy".

Next, "Deming's factors" (i.e., factors 1, 2, 4, 6, 7, 8, 9, and 13) were analyzed using second-order factor analysis in order to test whether they load on an overall construct that could be interpreted as a "TQM philosophy". Figure 4.3 shows the path diagram for the second-order factor model using "Deming's factors". The structural model and the measurement model can be mathematically represented as:

Structural equation: $$\underset{(8x1)}{\eta} = \underset{(8x1)}{\Gamma} \quad \underset{(1x1)}{\xi} + \underset{(8x1)}{\zeta} \tag{4.15}$$

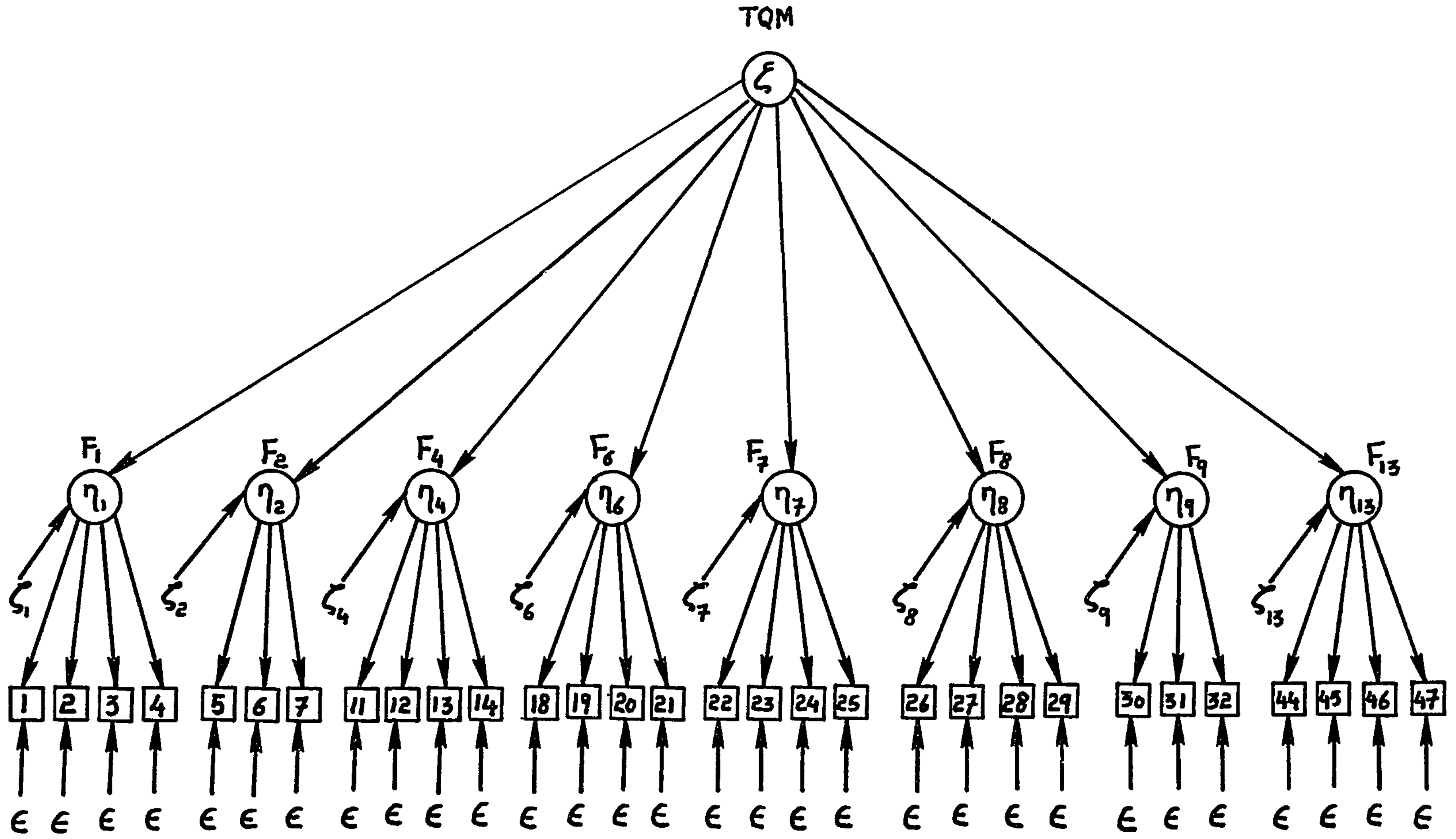
Measurement equation: $$\underset{(30x1)}{y} = \underset{(30x8)}{\Lambda_y} \quad \underset{(8x1)}{\eta} + \underset{(30x1)}{\epsilon} \tag{4.16}$$

Table 4.13: Estimates of the Second-Order Factor Analysis Model Using "Deming's Extracted Factors"

Parameter	Estimate	Z-Value	Parameter	Estimate	Z-Value
$\lambda 7,1$	1.00	N/A	$\lambda 13,5$	1.00	N/A
$\lambda 5,1$	0.89	12.11	$\lambda 12,5$	0.92	9.68
$\lambda 6,1$	0.67	8.29	$\lambda 11,5$	1.00	10.52
$\lambda 48,1$	0.75	9.57	$\lambda 8,5$	0.89	9.30
$\lambda 10,1$	0.90	12.30	$\lambda 14,5$	0.68	6.96
$\lambda 1,1$	0.76	9.63	$\lambda 21,6$	1.00	N/A
$\lambda 23,2$	1.00	N/A	$\lambda 18,6$	0.85	6.29
$\lambda 25,2$	0.85	14.87	$\lambda 19,6$	0.93	6.60
$\lambda 24,2$	0.89	16.64	$\lambda 2,7$	1.00	N/A
$\lambda 27,2$	0.64	9.12	$\lambda 3,7$	1.33	5.00
$\lambda 22,2$	0.76	12.01	$\lambda 43,8$	1.00	N/A
$\lambda 46,3$	1.00	N/A	$\lambda 29,8$	1.13	3.29
$\lambda 44,3$	1.15	12.82	$\gamma 1$	0.72	10.43
$\lambda 45,3$	1.01	11.35	$\gamma 2$	0.63	8.72
$\lambda 47,3$	0.83	8.90	$\gamma 3$	0.48	6.94
$\lambda 30,4$	1.00	N/A	$\gamma 4$	0.62	8.88
$\lambda 32,4$	0.99	8.33	$\gamma 5$	0.37	5.25
$\lambda 31,4$	1.18	9.73	$\gamma 6$	0.45	6.06
$\lambda 16,4$	1.04	8.70	$\gamma 7$	0.35	4.37
$\lambda 36,4$	0.94	7.94	$\gamma 8$	0.30	3.74

Note. Underlined estimates indicate those parameters that have been constrained to equal 1 in order to fix the scale of the latent variables.

Figure 4.3: Second-Order Factor Model Using a Subset of Deming's Factors



The results of the analysis were consistent with those obtained from analyzing "Deming's extracted factors". In other words, "Deming's factors" 1, 2, 4, 6, 7, 8, 9, and 13 appear to constitute an overall philosophy that may be interpreted as a "Total Quality Management philosophy".

The estimated coefficients, as depicted in Table 4.14, were positive and significant at the 0.05 level. Furthermore, the overall goodness of fit of the model measured by the ratio of χ^2/df was 2.82 (1121.44/397), which is indicative of a reasonably good fit.

4.9 The LISREL Model: Determinants of Quality Performance

Based upon the exploratory factor analysis findings, the impact of a "subset" of Deming's factors on quality performance is tested. The rationale behind using only a subset of the factors rather than the entire fourteen principles was due to the sample size limitation. Small sample sizes can lead to various computational difficulties such as convergence problems and negative error variances (Bentler and Chou, 1987).

Although there are no strict specifications for minimum sample sizes, Bentler (1985) has suggested that a sample size to parameter ratio of 5:1 is acceptable as a rule of thumb. Thus, in order to test the impact of Deming's fourteen factors on quality performance, 120 parameters would have to be estimated (see Table 3.5 on page 58), assuming θ_{δ}, θ_{ϵ}, and Φ

Table 4.14: Estimates of the Second-Order Factor Analysis Model Using "Deming's Factors"

Parameter	Estimate	Z-Value	Parameter	Estimate	Z-Value
λ1,1	1.00	N/A	λ26,8	1.00	N/A
λ2,1	0.62	5.27	λ27,8	0.86	7.07
λ3,1	0.86	7.17	λ28,8	0.93	7.50
λ4,1	0.91	7.56	λ29,8	0.52	4.42
λ5,2	1.00	N/A	λ30,9	1.00	N/A
λ6,2	0.69	7.30	λ31,9	1.39	8.84
λ7,2	1.10	11.62	λ32,9	1.16	8.22
λ11,4	1.00	N/A	λ44,13	1.00	N/A
λ12,4	0.85	7.88	λ45,13	0.88	13.06
λ13,4	1.20	10.05	λ46,13	0.87	12.83
λ14,4	0.82	7.61	λ47,13	0.73	9.75
λ18,6	1.00	N/A	γ1	0.65	9.13
λ19,6	1.47	5.70	γ2	0.32	4.72
λ20,6	0.88	4.37	γ3	0.49	7.52
λ21,6	1.24	5.36	γ4	0.48	7.14
λ22,7	1.00	N/A	γ5	0.54	7.41
λ23,7	1.34	11.87	γ6	0.37	5.43
λ24,7	1.19	10.84	γ7	0.62	8.56
λ25,7	1.12	10.17	γ8	0.58	8.00

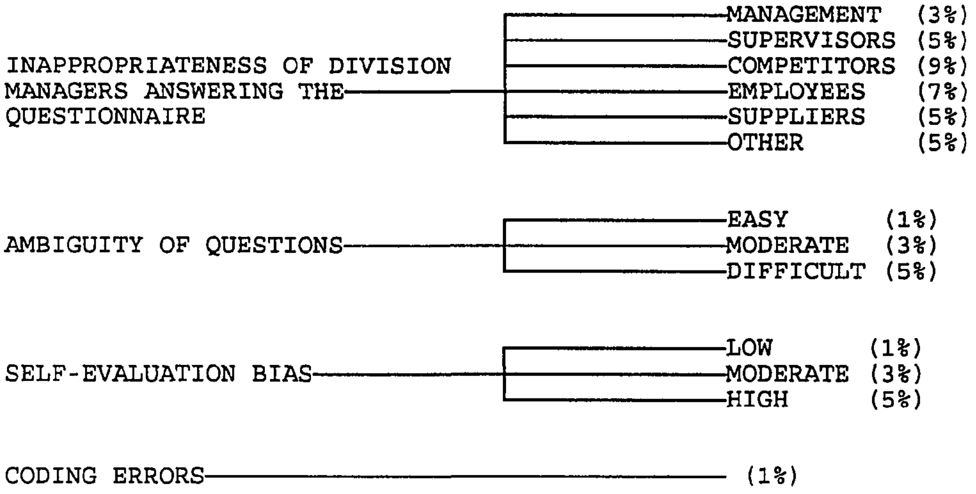
Note. Underlined estimates indicate those parameters that have been constrained to equal 1 in order to fix the scale of the latent variables.

are diagonal matrices, hence requiring a sample size of 600 using the 5:1 ratio suggested by Bentler.

To further constrict the number of estimated parameters in the LISREL model and to incorporate information about measurement quality, Hayduk (1987) suggests that the measurement reliabilities (i.e., the diagonal elements of θ_δ and θ_ϵ) should routinely be fixed rather than free. The fixed values are determined by first estimating the proportion of the variance of an indicator attributable to measurement error and then determining the values of the fixed θ coefficients by multiplying this proportion by the variance of the indicator.

The values used in determining the proportion of the error variance of an indicator are shown in Figure 4.4. As depicted in Figure 4.4, four sources of measurement errors were speculated to affect the reliabilities of the indicators. First, although the division manager was identified as the key informant in this study, there is a different degree of measurement error that is introduced when the division manager responds to questions related to top management, supervisors, competitors, employees, or suppliers. In particular, the measurement error is expected to be less when a division manager answers a question that is related to top management, rather than, say, answering a question that is related to supervisors or employees. For example, face to face interactions between top management and division managers are likely to be more frequent than between division managers and

Figure 4.4. Scheme Used in Fixing Measurement Errors



Note· The percentages indicate the percentage of the indicator variances that have been attributed to the different sources of measurement errors and hourly employees hourly employees. The percentage error variances were subjectively estimated as shown in Figure 4.4, based on presumed frequency of interactions of the various targets/persons.

Second, the complexity of the survey questions was also hypothesized to introduce certain measurement errors. Accordingly, based upon the degree of ambiguity and complexity of the survey items, questions were categorized as "easy", "moderately easy", and "difficult". For example, a question such as "employees are trained in quality related matters" was classified as "easy", in comparison to a question such as "top management makes long term plans" which was classified as "moderate".

Third, self-evaluation bias was also considered as another source of measurement error. Self-evaluation bias refers to the possible inherent prejudice that may be exhibited by the respondents in order to look good in the eyes of others (e.g., "our product is better than our competitors", "we do the right things", "our employees are happy"). Finally, the last source of measurement error was attributed to the possibility of coding errors. A 1% error was allowed for an occasional keypunch mistake or for transposing numbers inadvertently.

In Table 4.15, column A represents measurement errors attributed to the appropriateness of the person answering the questionnaire, column B represents measurement errors

Table 4.15: Estimates of the Diagonal Elements of $\boldsymbol{\theta}$

	A	B	C	D	Total	Variance	$\boldsymbol{\theta}$
X1	3%	3%	3%	1%	10%	0.927	0.093
X2	3	1	1	1	6	1.497	0.090
X3	3	1	1	1	6	0.937	0.056
X4	3	1	1	1	6	0.989	0.059
X5	3	1	3	1	8	1.004	0.080
X6	3	3	3	1	10	1.248	0.125
X7	3	3	3	1	10	1.214	0.121
X8	5	1	1	1	8	0.726	0.058
X9	5	1	1	1	8	1 151	0.092
X10	3	1	3	1	8	1.018	0.081
X11	5	1	3	1	10	1.101	0.110
X12	5	1	1	1	8	0.931	0.074
X13	5	1	1	1	8	0.866	0.069
X14	5	1	1	1	8	0.902	0.072
X15	5	1	1	1	8	0 758	0.061
X16	5	1	1	1	8	1.039	0.083
X17	3	1	1	1	6	1.147	0.069
X18	7	1	1	1	10	1.525	0.153
X19	7	1	1	1	10	1.098	0.110
X20	7	1	1	1	10	0.684	0.068
X21	5	1	1	1	8	1.259	0.100
X22	5	1	1	1	8	0.614	0.049
X23	5	5	1	1	12	0.854	0.102
X24	5	5	1	1	12	0.825	0.099
X25	5	5	1	1	12	0 935	0.112
X26	7	1	1	1	10	0 795	0.080
X27	7	1	1	1	10	0.660	0.066
X28	7	3	1	1	12	0.973	0.117
X29	7	1	3	1	12	1.215	0.146
X30	5	3	1	1	10	0.795	0 080
X31	5	1	3	1	10	1.002	0 100
X32	5	1	3	1	10	0.868	0.087
X33	3	3	3	1	10	0.888	0.089
X34	3	5	3	1	12	1.291	0 155
X35	3	5	3	1	12	1 730	0.208
X36	5	1	3	1	10	0.877	0.088
X37	5	5	1	1	12	1.112	0.133
X38	5	3	3	1	12	1.276	0.153
X39	5	5	1	1	12	2 074	0.249
X40	5	5	5	1	16	0.778	0.124
X41	5	1	3	1	10	1.276	0.128
X42	5	1	3	1	10	1.297	0.130
X43	3	1	5	1	10	1 168	0.117
X44	5	3	1	1	10	1.367	0.138
X45	5	3	1	1	10	1.334	0.133
X46	5	5	1	1	12	1.367	0.164
X47	5	3	1	1	10	1.334	0.133
X48	3	1	3	1	8	1.078	0 086
X49	3	3	3	1	10	1.139	0.114
X50	3	1	1	1	6	1.374	0.082
Q1	5	5	1	1	12	0.600	0.072
Q2	5	5	3	1	14	0.574	0.080
Q3	5	3	3	1	12	0.516	0.062

Note: Q1, Q2, and Q3 are the quality performance indicators attributed to the ambiguity of the questions, column C represents measurement errors attributed to self-evaluation bias, while column D represents measurement errors arising from the possibility of coding errors. The "Total" column represents the sum of all the error proportions (i.e., the sum of columns A through D). The last column, the fixed θ coefficients that may be employed in the LISREL model, is simply the multiplication of the variance of the item and the sum of the error proportions.

Factors 2, 4, 7, 9, and 13, a subset of Deming's fourteen factors, were selected to evaluate their impact on quality performance. The justification behind using these specific variables is based upon the exploratory factor analysis findings Specifically, the first five extracted factors obtained from the exploratory factor analysis closely resemble the "actual" selected factors (i.e., factors 2, 4, 7, 9, and 13), and they further account for 66% (44.2/67.4) of the total variance that the entire fourteen extracted factors account for. Moreover, as depicted in Table 4.10, beyond factor 5, each additional extracted factor explained less than 3.5% of the remaining variance in the data.

4.9.1 LISREL Model 1: Determinants of "Customer Retention Rate"

In this model, the influence of Deming's factors 2, 4, 7, 9, and 13 on customer retention rate compared to the competition (Q1) are estimated. The path diagram exhibiting this relationship is shown in Figure 4.5. As depicted in Figure 4.5, the LISREL model can be mathematically represented by the following three equations:

$$\underset{(1\text{x}1)}{\eta} = \underset{(1\text{x}5)}{\Gamma}\ \underset{(5\text{x}1)}{\xi} + \underset{(1\text{x}1)}{\zeta} \tag{4.17}$$

$$\underset{(18\text{x}1)}{\mathbf{x}} = \underset{(18\text{x}5)}{\Lambda_x}\ \underset{(5\text{x}1)}{\xi} + \underset{(18\text{x}1)}{\delta} \tag{4.18}$$

$$\underset{(1\text{x}1)}{\mathbf{y}} = \underset{(1\text{x}1)}{\Lambda_y}\ \underset{(1\text{x}1)}{\eta} + \underset{(1\text{x}1)}{\epsilon} \tag{4.19}$$

This model was estimated using the LISREL VII program (Joreskog and Sorbom, 1989), fixing the Θ_δ and the Θ_ϵ coefficients at the hypothesized values contained in Table 4.15[6]. The overall goodness of fit of the model measured by the χ^2/df statistic was 30.7, indicating an inadequate fit. The largest modification index was associated with parameter $\Theta_\delta(7,7)$, the error variance represented by variable X14. Upon freeing parameter $\Theta_\delta(7,7)$ and re-estimating the model, the overall goodness of fit of the model measured by the χ^2/df statistic was 25.4, which is still indicative of a poor fit. Next, based upon the modification indices information, $\Theta_\delta(8,8)$, the error variance represented by variable X22, $\Theta_\delta(12,12)$, the error variance represented by variable X30, and $\Theta_\delta(5,5)$, the error variance represented by variable X12, were successively freed and the model was re-estimated upon each relaxation The next largest modification index was

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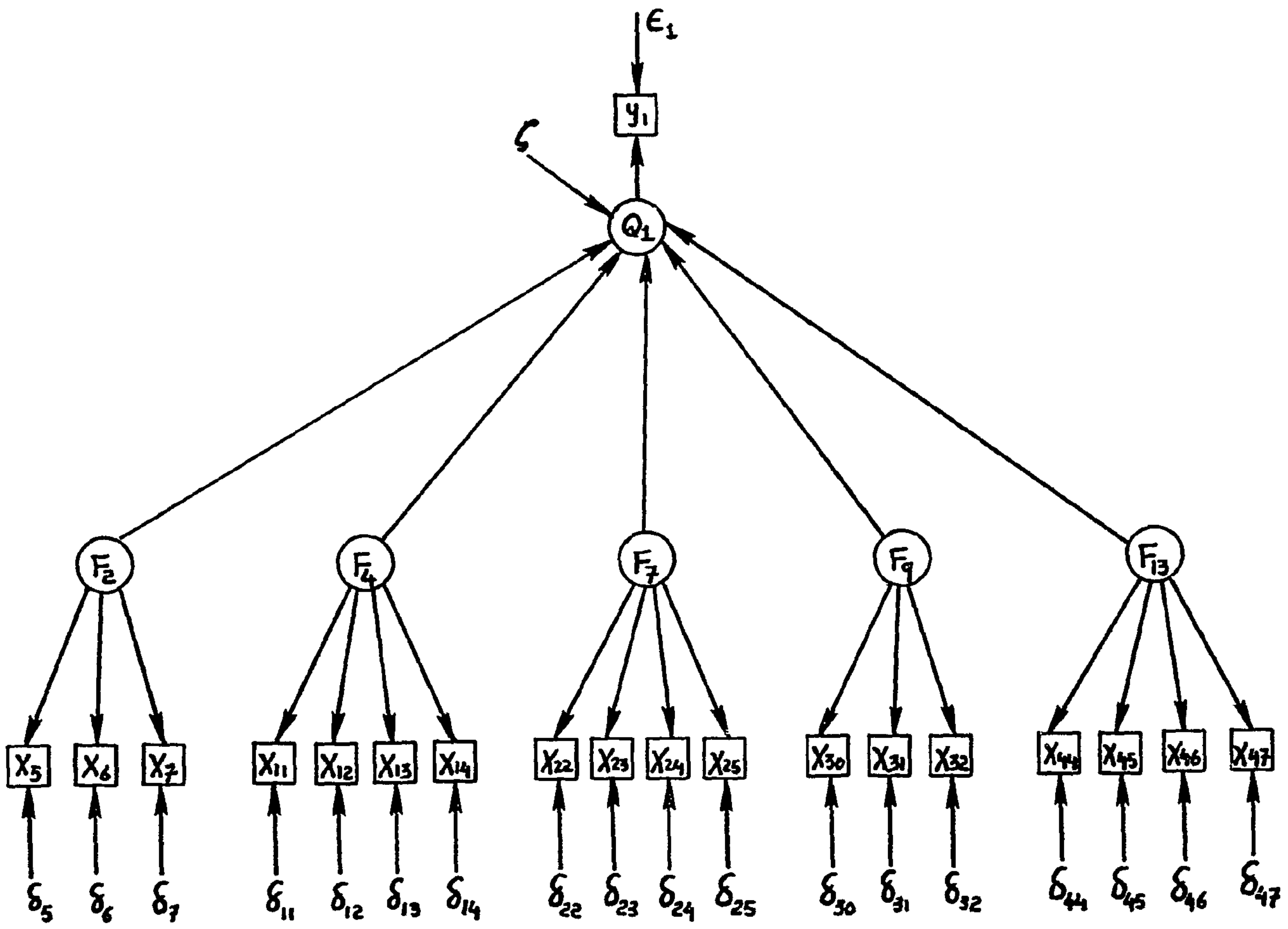
[6] The solution failed to converge when Θ_δ was freed to be optimized.

Figure 4 5: LISREL Model 1



associated with parameter $\theta_\delta(2,2)$, the error variance represented by variable X6. However, upon relaxing this parameter and re-estimating the model, the solution failed to converge. Numerous efforts were undertaken to overcome the lack of convergence, including providing different starting values for the estimated parameters and increasing the number of iterations of the LISREL program (Hayduk, 1987).

As described by Bentler and Chou (1987), failure to converge is a result of the computer program encountering an infinite or very lengthy iterative process. Bentler and Chou provide a number of reasons for lack of convergence, including a very poorly fitting model, a non-linear model, incorrect starting values, or under-identification of parameters. The most likely explanation for the occurrence of this problem is that the model is empirically under-identified (Joreskog and Sorbom, 1989). Identification problems have also occurred when fewer than three indicators per latent variable were used (Bentler and Chou, 1987). In addition, using a one indicator scale (Q1) as a dependent latent variable makes it impossible to assess the reliability of this survey item.

Table 4.16 contains the maximum likelihood estimates which were obtained from the last iteration of the converged solution. The overall goodness of fit of the model remained inadequate, yielding a χ^2/df statistic of 13.6. Furthermore, as depicted in Table 4.16, although factors 4, 9, and 13 were significant at the 0.05 level, it should be noted that such

Table 4.16. Maximum Likelihood Estimates of LISREL Model 1

Parameter	Estimate	Z Value	Parameter	Estimate	Z-Value
λx(1,2)	1.000	N/A	φ1	0.756	8 45
λx(2,2)	0.851	23 85	φ2	0.736	8.22
λx(3,2)	0.963	26.13	φ3	0 456	5.32
λx(4,4)	1 000	N/A	φ4	0.309	4.03
λx(5,4)	0.705	10.50	φ5	0.815	8.25
λx(6,4)	1.063	29.42	ζ	0.500	4.10
λx(7,4)	0.697	9.97	δ1	0.080	N/A
λx(8,7)	1.000	N/A	δ2	0.125	N/A
λx(9,7)	1 326	12.39	δ3	0.121	N/A
λx(10,7)	1.279	12.37	δ4	0.110	N/A
λx(11,7)	1.381	12.39	δ5	0 612	9.00
λx(12,9)	1.000	N/A	δ6	0 069	N/A
λx(13,9)	1.557	8.68	δ7	0.669	9.03
λx(14,9)	1.656	8.74	δ8	0.559	8.96
λx(15,13)	1.000	N/A	δ9	0.102	N/A
λx(16,13)	0.866	25.86	δ10	0.099	N/A
λx(17,13)	0.932	25 40	δ11	0 112	N/A
λx(18,13)	0 857	25 70	δ12	0 661	9 04
λy(1,1)	1.000	N/A	δ13	0 100	N/A
γ1	0.001	0 02	δ14	0.087	N/A
γ2	0.18	2.57	δ15	0.138	N/A
γ3	0.17	1 77	δ16	0 133	N/A
γ4	0.67	5 76	δ17	0 164	N/A
γ5	0 26	3.94	δ18	0.133	N/A
			ε1	0.072	N/A

Note Underlined estimates indicate the parameters that have been constrained in the model statistical significance results may be unstable considering the lack of fit of the overall model.

4.9.2 LISREL Model 2: Determinants of "Features of Products/Services Compared to the Competition"

In this model, the influence of Deming's factors 2, 4, 7, 9, and 13 on the dependent variable "the features of your products/services compared to the competition" (Q2) were examined. The path diagram and the mathematical representation of this model are analogous to LISREL model 1 that was described previously. However, in estimating the parameters of this model, the coefficients of matrix θ_δ were set free, while θ_ϵ was fixed at 0.080. The maximum likelihood estimates are contained in Table 4.17.

The overall goodness of fit of the model measured by the χ^2/df statistic was 3.7, which is indicative of an adequate fit. Factors 7 (instituting leadership), 9 (breaking down barriers between departments), and 13 (instituting education and self-improvement) were significant at the 0.05 level, and so were all the measurement coefficients (i.e., the elements of Λ_x and Λ_y).

4.9.3 LISREL Model 3: Determinants of "Frequency of Repeating Work Because it was not Done Correctly the First Time"

In this model, the influence of Deming's factors 2, 4, 7, 9, and 13 on the dependent variable "How often does your organization have to repeat work because it was not done correctly the first time?" (Q3) were tested.

Table 4.17 Maximum Likelihood Estimates of LISREL Model 2

Parameter	Estimate	Z Value	Parameter	Estimate	Z-Value
λx(1,2)	1.000	N/A	φ1	0.559	5.56
λx(2,2)	0.784	8.02	φ2	0.686	6.61
λx(3,2)	1.255	9.68	φ3	0.447	6.00
λx(4,4)	1.000	N/A	φ4	0.271	4.62
λx(5,4)	0.874	12.38	φ5	0.837	7.67
λx(6,4)	0.939	14.26	ζ	0.633	2.60
λx(7,4)	0.685	9.60	δ1	0.406	5.92
λx(8,7)	1.000	N/A	δ2	0.712	8.49
λx(9,7)	1.429	15.33	δ3	0.121	1.44
λx(10,7)	1.238	13.81	δ4	0.360	5.95
λx(11,7)	1.258	13.36	δ5	0.522	7.57
λx(12,9)	1.000	N/A	δ6	0.324	6.01
λx(13,9)	1.606	10.03	δ7	0.680	8.49
λx(14,9)	1.662	10.04	δ8	0.511	8.74
λx(15,13)	1.000	N/A	δ9	0.087	3.11
λx(16,13)	0.881	14.98	δ10	0.279	7.52
λx(17,13)	0.865	15.05	δ11	0.363	7.95
λx(18,13)	0.706	10.69	δ12	0.638	8.60
λy(1,1)	1.000	N/A	δ13	0.291	4.95
γ1	-0.079	-0.78	δ14	0.306	4.90
γ2	0.057	0.63	δ15	0.161	4.12
γ3	0.376	3.45	δ16	0.370	7.40
γ4	0.449	2.77	δ17	0.352	7.36
γ5	0.248	3.30	δ18	0.592	8.58
			ε1	0.080	N/A

Note. Underlined estimates indicate the parameters that have been constrained in the model.

The coefficients of matrix Θ_δ were set free, while coefficient θ_ϵ was fixed at 0.062, as hypothesized in Table 4.15. The overall goodness of fit of the model measured by the χ^2/df statistic was 3.7, which is indicative of an adequate fit. Moreover, factors 2 (adopting the new philosophy) and 9 (breaking down barriers between departments) were significant at the 0.05 level, and so were all the measurement coefficients (i.e., the elements of Λ_x and Λ_y) as indicated by Table 4.18.

4.9.4 LISREL Model 4: Determinants of "Features of Products/Services Compared to the Competition" <u>and</u> "Frequency of Repeating Work Because it was not Done Correctly the First Time"

In this model, the influence of Deming's factors 2, 4, 7, 9, and 13 on the dependent variables Q1 (features of products/services compared to the competition) and Q2 (frequency of repeating work because it was not done correctly the first time) were examined. The path diagram exhibiting this relationship is shown in Figure 4.6.

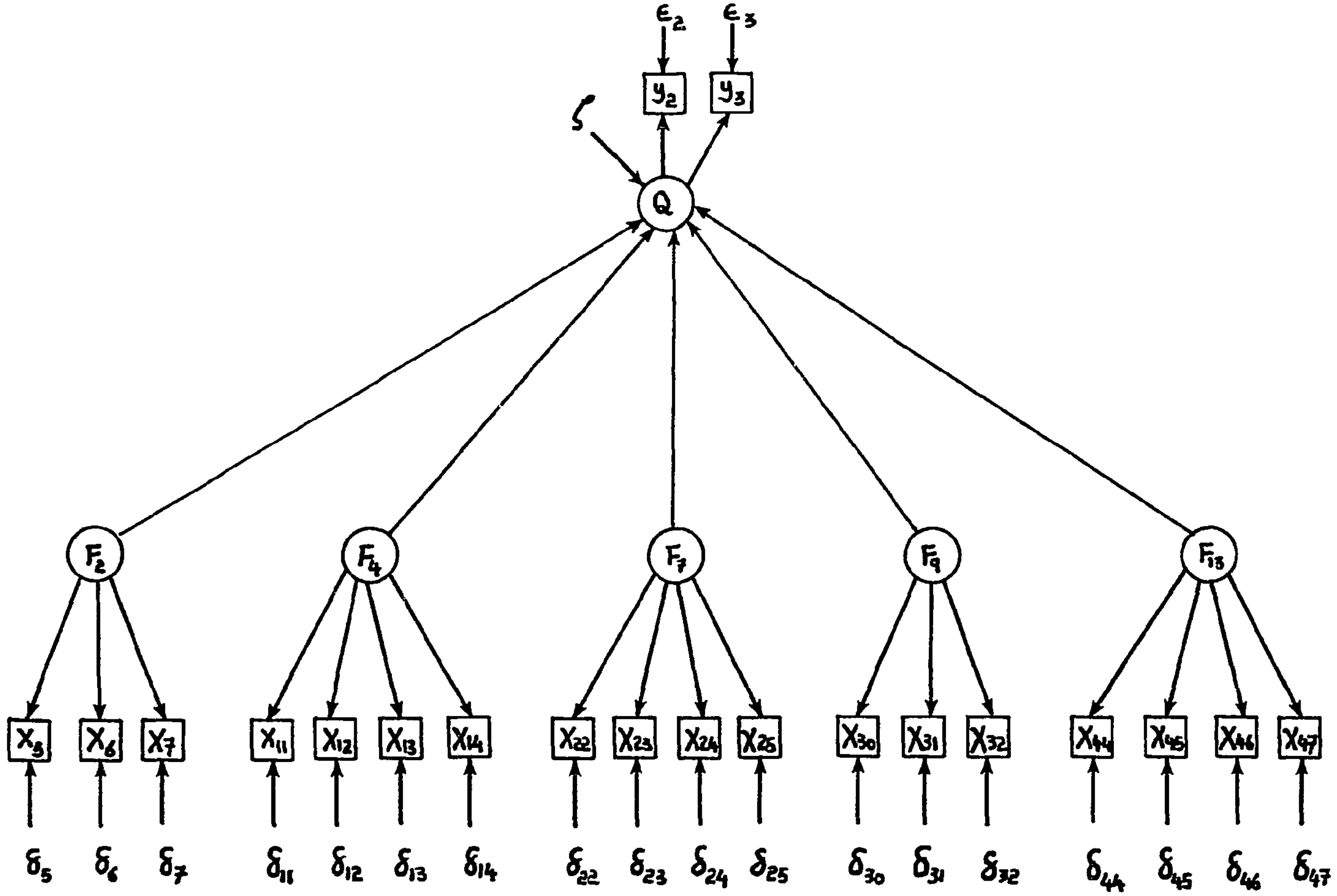
The coefficients of matrix Θ_δ were set free, while the coefficients of $\theta_{\epsilon,Q2}$ and $\theta_{\epsilon,Q3}$ were fixed at 0.080 and 0.062, respectively, as hypothesized in Table 4.15. The overall goodness of fit of the model measured by the χ^2/df statistic was 9 5, indicating an inadequate fit. The largest modification index was associated with parameter $\theta_{\epsilon,Q2}$, the error variance represented by parameter Q2. Upon freeing parameter $\theta_{\epsilon,Q2}$ and re-estimating the model, the oveall

Table 4.18 Maximum Likelihood Estimates of LISREL Model 3

Parameter	Estimate	Z Value	Parameter	Estimate	Z-Value
λx(1,2)	1.000	N/A	φ1	0.684	5.84
λx(2,2)	0.673	7.28	φ2	0.549	6.12
λx(3,2)	1.060	9.79	φ3	0.562	6.28
λx(4,4)	1.000	N/A	φ4	0.412	4.41
λx(5,4)	0.855	10.32	φ5	0.822	7.67
λx(6,4)	1.208	13.98	ζ	0.598	3.38
λx(7,4)	0.859	10.34	δ1	0.329	4.65
λx(8,7)	1.000	N/A	δ2	0.699	8.56
λx(9,7)	1.246	16.19	δ3	0.220	3.04
λx(10,7)	1.095	14.46	δ4	0.461	7.37
λx(11,7)	1.155	14.12	δ5	0.608	8.32
λx(12,9)	1.000	N/A	δ6	0.189	3.49
λx(13,9)	1.378	8.39	δ7	0.610	8.31
λx(14,9)	1.210	8.24	δ8	0.503	8.51
λx(15,13)	1.000	N/A	δ9	0.103	3.64
λx(16,13)	0.836	14.90	δ10	0.276	7.43
λx(17,13)	0.895	16.10	δ11	0.355	7.72
λx(18,13)	0.790	12.26	δ12	0.591	8.07
λy(1,1)	1.000	N/A	δ13	0.218	3.30
γ1	0.240	2.91	δ14	0.394	6.10
γ2	-0.019	-0.18	δ15	0.169	4.28
γ3	0.130	1.34	δ16	0.382	7.66
γ4	0.563	4.92	δ17	0.341	7.13
γ5	0.103	1.39	δ18	0.584	8.37
			ε1	0.062	N/A

Note Underlined estimates indicate the parameters that have been constrained in the model.

Figure 4.6: LISREL Model 4



goodness of fit of the model measured by χ^2/df statistic was 3.6, indicating an adequate fit. Moreover factors 2 (adopting the new philosophy) and 9 (breaking down barriers between departments) were significant at the 0.05 level, and so were all the measurement coefficients (i.e., the elements of Λ_x and Λ_y) as indicated by Table 4.19[7].

In conclusion, the various hypothesized LISREL models suggest that the global fit of the model and the impact of Deming's factors on quality performance are dependent on the way one defines quality. For example, when quality was defined as "customer retention rate compared to the competition", the global fit of the model at convergence was inadequate (χ^2/df=13.6), but factors 4, 9, and 13 were significant at the 0.05 level. When quality was defined as "attributes of product compared to the competition", the global fit of the model was adequate (χ^2/df=3.7), but only factors 7 (instituting leadership), 9 (breaking down barriers between departments, and 13 (instituting education and self-improvement), were significant at the 0.05 level. When quality was defined as "frequency of repeating work because it was not done correctly the first time", the global fit of the model was adequate (χ^2/df=3.7), and only factors 2 (adopting the new philosophy) and 9 (breaking down barriers between departments) were significant at the 0.05 level. Finally, when quality was

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[7] When quality performance was represented by Q1, Q2, <u>and</u> Q3, convergence problems developed in estimating the LISREL model.

Table 4.19 Maximum Likelihood Estimates of LISREL Model 4

Parameter	Estimate	Z Value	Parameter	Estimate	Z-Value
$\lambda x(1,2)$	1.000	N/A	$\phi 1$	0.753	7.00
$\lambda x(2,2)$	0.672	10.13	$\phi 2$	0.545	5.70
$\lambda x(3,2)$	0.944	16.16	$\phi 3$	0.530	5.61
$\lambda x(4,4)$	1.000	N/A	$\phi 4$	0.433	5.41
$\lambda x(5,4)$	0.853	8.98	$\phi 5$	0.830	7.50
$\lambda x(6,4)$	1.216	11.82	ζ	0.086	3.00
$\lambda x(7,4)$	0.867	9.04	$\delta 1$	0.281	4.65
$\lambda x(8,7)$	1.000	N/A	$\delta 2$	0.701	8.53
$\lambda x(9,7)$	1.297	13.09	$\delta 3$	0.279	5.01
$\lambda x(10,7)$	1.149	11.89	$\delta 4$	0.463	7.31
$\lambda x(11,7)$	1.146	11.39	$\delta 5$	0.611	8.30
$\lambda x(12,9)$	1.000	N/A	$\delta 6$	0.184	3.23
$\lambda x(13,9)$	1.343	12.38	$\delta 7$	0.609	8.28
$\lambda x(14,9)$	1.168	11.31	$\delta 8$	0.504	8.56
$\lambda x(15,13)$	1.000	N/A	$\delta 9$	0.096	3.24
$\lambda x(16,13)$	0.851	13.27	$\delta 10$	0.275	7.27
$\lambda x(17,13)$	0.891	14.01	$\delta 11$	0.359	7.84
$\lambda x(18,13)$	0.745	10.36	$\delta 12$	0.588	8.18
$\lambda y(1,1)$	1.000	N/A	$\delta 13$	0.219	4.03
$\lambda y(2,1)$	2.613	4.57	$\delta 14$	0.396	6.83
$\gamma 1$	0.092	2.51	$\delta 15$	0.166	4.05
$\gamma 2$	-0.007	-0.18	$\delta 16$	0.379	7.52
$\gamma 3$	0.051	1.38	$\delta 17$	0.342	7.07
$\gamma 4$	0.212	3.43	$\delta 18$	0.587	8.46
$\gamma 5$	0.041	1.40	$\epsilon 1$	0.863	4.57
			$\epsilon 2$	0.062	N/A

defined by "features of products/services compared to the competition" and "frequency of repeating work because it was not done correctly the first time" the global fit of the model was adequate (χ^2/df=3.6), and only factors 2 (adopting the new philosophy) and 9 (breaking down barriers between departments) were significant at the 0.05 level.

Interestingly, factor 9 was consistently significant in all the hypothesized LISREL models, including the regression models that tested the individual influence of Deming's factors on quality performance. This may signal the importance of communications among departments (e.g., design, engineering, and marketing) as a critical component to increasing customer satisfaction and improving productivity.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Summary of Results

Deming's philosophy of quality management has been praised by many quality experts as the road map to creating a quality planning and control environment that encourages teamwork, communication, pride in workmanship, and never-ending improvement. Although Deming communicates his theory of quality management practices in terms of his fourteen principles, there is little guidance in the literature concerning how to measure or implement such practices. For example, "creating constancy of purpose" (factor 1) and "adopting the new philosophy" (factor 2) would be of little use to managers without providing them with specific guidelines on how to interpret, implement, and measure such practices.

Moreover, although Deming's factors have been described by many quality experts as the primary components of the "Total Quality Management" philosophy, no empirical research has yet studied the inter-relationships among the fourteen factors. For example, although factor 2 (adopting the new philosophy) and factor 14 (taking action to accomplish the transformation) may be conceptually inter-related, this remains to be empirically tested. Furthermore, there is little empirical proof of the influence of the Deming philosophy on performance measures such as quality improvement, market share, profitability, productivity, or employees' morale.

To shed a new light on Deming's philosophy and to overcome some of the shortcomings that exist in the current quality literature, this study has developed survey instruments to measure the degree of implementation of Deming's principles. These measures can be used by quality managers and industry practitioners to assess the status of quality management in order to diagnose training needs, and to direct improvements in the quality area. Equally important, by identifying and prioritizing specific areas for improvement, top management can allocate its limited resources efficiently, targeting those areas that are in immediate need for improvement.

This study used manufacturing and service oriented firms of different sizes in measuring subjects' responses to questions about the extent of implementation of Deming's fourteen principles and the firms' quality performance. A total of 184 respondents (173 division managers and 11 hourly employees) completed the survey, yielding a 46% response rate. The number of responses received from service type firms was 110, while the number of responses received from manufacturing type firms was 74.

The psychometric properties of the measures were evaluated for their reliability (i.e., internal consistency) and validity. The internal consistency of the scales, which measures the degree of homogeneity or inter-relatedness among the suggested measures of each Deming factor, yielded alpha values (i.e., Cronbach's alpha) above 0.60, except for factors 3 (ceasing dependence on mass inspection), 10 (eliminating slogans and exhortations), 12 (removing barriers to pride in workmanship), and 14 (taking action to accomplishing the transformation). The weak internal consistency of the measures of factors 3, 10, 12, and 14 may be attributed to the high variance of the degree of implementation of the practices measuring these factors.

The suggested measures of Deming's factors were evaluated for their validity to test whether the practices measure what they are supposed to measure. The criterion validity was assessed using regression analysis, by examining the degree of association between Deming's factors and quality performance. In some regression models, the individual effect of Deming's principles on quality performance was tested. In other models, the collective influence of the Deming philosophy as a whole was examined.

It should be mentioned, however, that the strategy of testing the individual influence of Deming's factors on quality performance would probably be highly criticized by Deming and his advocates who stress that the Deming philosophy must be implemented as a whole in order to reap its fruitfulness. In fact, when the help of the Philadelphia Area Council for Excellence (PACE) organization, an avid supporter of the Deming philosophy, was enlisted for supporting this study, they were highly critical of the intention to test or rank the individual importance of the factors.

The regression analysis results showed that the models that took into account the collective and additive influence of Deming's fourteen factors (i.e., the models that tested the total average effects of Deming's principles) were more superior, in terms of fit, to the models that considered the multiplicative effects of Deming's principles (i.e., the models that tested interactions among Deming's principles). The results also showed that the multiplicative effects of Deming's principles have no impact on quality performance, when the additive effects of Deming's principles are accounted for (i.e., held constant).

Confirmatory factor analysis was used to test the construct validity of the factors and to further examine the inter-relationships among them. The results showed that the items used to operationalize the factors had significant loadings on their hypothesized constructs except for items X33, X34, X35 (indicators of factor 10), and X39 (an indicator of factor 12). The failure of such items to load significantly on their hypothesized constructs may be attributed to the dissimilarity in content, as defined by

Deming, of these items. In other words, the items were not very homogeneous, and thus, they may be measuring more than one factor. For example, although item X39 ("performance appraisals are used to rank employees") is described by Deming as a barrier to pride in workmanship, this item, however, is different in content from the rest of the items that are used to measure this factor (i.e., factor 12).

Moreover, the confirmatory factor analysis revealed that several of Deming factors are correlated, a finding that has been acknowledged in the literature but never demonstrated empirically. In specific, factor 2 (adopting the new philosophy) and factor 14 (taking action to accomplishing the transformation) were correlated; factor 3 (ceasing reliance on mass inspection) and factor 6 (instituting training) were correlated, factor 5 (improving constantly the system of production or service) and factor 9 (breaking down barriers between departments) were correlated; factor 7 (instituting leadership) and factor 8 (driving out fear) were correlated, and factor 11 (eliminating numerical quotas) and factor 12 (removing barriers to pride in workmanship) were correlated. Such results may support the notion that at least some of Deming's fourteen factors are in fact inter-related.

Second-order factor analysis was conducted to test the premise that Deming's factors constitute an overall concept, resembling "Deming's total quality management philosophy". First, an exploratory principal component factor analysis was used as a means of ascertaining the minimum number of hypothetical factors that account for the maximum observed covariation. The rationale behind this approach was: First, to find out whether the items load on the same factors that were hypothesized in the confirmatory factor analysis; second, to reduce the number of factors to a smaller subset that accounts for the maximum variance in the data, in order to reduce the number of estimated parameters in the LISREL analyses, and lessen the chances of encountering computational problems arising from using a sample size of 173.

The exploratory factor analytic approach extracted fourteen factors of which eight were interpretable and quite similar to eight of Deming's factors (Factors 1, 2, 4, 6, 7, 8, 9 and 13). These eight extracted factors may be interpreted, respectively, as top management commitment, instituting leadership, instituting education, communicating to improve quality, supplier management, instituting training, product innovation, and providing assurance to employees.

The second-order factor analysis conducted on these eight extracted factors demonstrated that they load on an overall construct that may be interpreted as some "Total Quality Management philosophy". Similar results were also obtained using Deming's factors 1, 2, 4, 6, 7, 8, 9, and 13 which also loaded on an overall construct. These findings support the premise that Deming's factors represent an overall philosophy, but fall short of implying that they must be implemented in concert with each other.

Finally, the impact of Deming's factors 2, 4, 7, 9, and 13, on each hypothesized quality performance measure (i.e., customer retention rate, features of products, and repeat work) were tested using Linear Structural Relational modeling (i.e., LISREL). The justification for selecting this specific subset of independent variables was based on the exploratory factor analysis. Specifically, this subset closely resembled the first five extracted factors which explained 66% of the total variation that was accounted for by the entire fourteen extracted factors. When "customer retention rate" was used as the dependent variable in the LISREL model, factors 4, 9, and 13 were significant, although the overall fit of the model was inadequate (χ^2/df=13.6). However, when the "features of the products" was used as the dependent variable, factors 7, 9, and 13 were significant, and the overall fit of the model was adequate (χ^2/df=3.7). When "repeating work" was used as the dependent variable in the model, factors 2 and 9 were significant, and the overall fit of the model was satisfactory (χ^2/df=3 7). Finally, when "features of the products" and "repeating work" were used as dependent variables, factors 2 and 9 were significant, and the overall fit of the model was satisfactory (χ^2/df=3.6). Communications among departments (factors 9) appeared to be a significant factor influencing quality performance in all of the tested models, including the regression models.

5.2 Limitations and Future Research

One of the limitations of this study is attributed to the choice of variables of interest. First, there may be a so-called "size-effect" on quality. Literature shows that various financial and managerial variables (e.g., extent of practice of scientific management practices, extent of long-term planning, extent of research and development emphasis, etc.) are empirically related to firm size. It is very conceivable that "size" may be a major determinant of quality. However, size is not considered as a covariate here.

Second, there unarguably exists some "Experience with Demingization" effect. That is, the duration of time over which a firm has been devoted to Demingization is a major determinant of quality. This impacts both the selection of indicators that have been emphasized by each firm and also the success in implementation of these practices. In future studies, investigating the association between quality and this "experience" variable may add to our knowledge of the subject.

Third, all measures of quality used are perceptual in nature. That is, questions related to customer retention rates and attributes of products are asked to managers, rather than being asked to consumers and independent evaluation agencies/trade organizations, respectively. Since all measures of quality are the opinions of division managers, they may be "biased". Even if the manager is completely unbiased, theses measures are subject to high measurement errors since the manager of a firm does not have complete information on the retention-rate and product attributes of the competitor's products.

Another limitation of this study is attributed to sampling methods/survey design. First, almost all of the surveyed firms were committed to quality improvement programs, and this may have resulted in reducing the variance of the variables. For example, as illustrated by the histograms in Appendix C, many variables were negatively skewed, which is indicative of firms' devotion to quality programs. Thus, in future research, a control sample (i.e., a sample consisting of firms that may not be totally committed to quality) should be included to be able capture the effect of the Deming philosophy on quality performance.

Second, the use of "division managers" as the respondents may have resulted in managers with completely different backgrounds and at completely different hierarchical levels answering the survey questions. For example, in smaller size firms, some division managers were vice-presidents.

Another limitation of this study is attributed to modeling/estimation procedures. First, the sample size used in the LISREL analyses is considered small if one uses Bentler's 5:1 rule of thumb. Therefore, it would be interesting to cross validate the findings using a much larger sample.

Second, while regression models assume there exists certain covariates which affect quality (i.e., A, B, and S), the LISREL models did not incorporate these covariates into the analyses. Moreover, although the "multiplicative" effects of Deming's principles were tested using regression analyses, the LISREL models did not incorporate such effects.

The results found in this study are encouraging. However, further research needs to be done to cross validate the findings. Moreover, although quality performance was selected as the success criterion in this study, future research can be directed towards examining the impact of Deming's practices on other non-survey performance measures such as productivity, profitability, market share, and employees' morale.

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APPENDIX A

QUESTIONNAIRE

The following statements describe a number of organizational characteristics and practices. Please indicate whether these statements are true of **top management** in your primary place of employment. Use the following response scale:

Not At All True	Slightly True	Somewhat True	Mostly True	Completely True
0	1	2	3	4

1 Top management makes long-term plans.... ..... 0 1 2 3 4

2\. Top management does not provide for research and development 0 1 2 3 4

3\. Top management provides for new technology. .. 0 1 2 3 4

4 Top management promotes employee training/education 0 1 2 3 4

5 Top management is committed to quality improvement as a way to increase profits 0 1 2 3 4

6 Top management is not committed to setting objectives for quality improvement. 0 1 2 3 4

7 Top management is committed to continuous quality enhancement as a primary goal.......... 0 1 2 3 4

8\. Top management supports the belief that quality must be "built into" the product and not "inspected into" it.... .... 0 1 2 3 4

9\. Top management assesses its competitors in order to improve the product/service........ 0 1 2 3 4

10 Top management sets unrealistic goals for its employees 0 1 2 3 4

11 Top management provides its workers with the methods/procedures to meet goals............ ...0 1 2 3 4

12\. Top management makes its quality improvement policies visible to all employees............. 0 1 2 3 4

13 Top management uses internal or external consultants to implement its quality improvement policies......... .... 0 1 2 3 4

14 Top management does not execute its quality
improvement policies 0 1 2 3 4

15. Top management, not the hourly worker, takes
responsibility to removing obstacles that cause
defects/errors........ .... 0 1 2 3 4

16 Top management uses vague slogans (e.g , "Do it
right the first time") in communicating with its
employees 0 1 2 3 4

Please indicate the extent to which the following statements are true of the **hourly employees** in your primary place of employment

17 Employees are not trained in statistical
improvement techniques. 0 1 2 3 4

18 Employees are trained in quality-related
matters 0 1 2 3 4

19 Employees are trained in specific
work-related skills 0 1 2 3 4

20 Employees feel they have no job security.. . 0 1 2 3 4

21 Employees express new ideas related to
improving work methods.. .. .. 0 1 2 3 4

22 Employees seek their supervisors' assistance
when unsure of their tasks..... . . .. 0 1 2 3 4

23 Employees are not afraid to report working
conditions that interfere with quality. 0 1 2 3 4

Please indicate the extent to which the following statements are true regarding the **suppliers** in your primary place of employment

24 Suppliers use statistical quality control
techniques 0 1 2 3 4

25 Supplier selection is based on both quality
and price rather than price alone.. . . .. 0 1 2 3 4

26 Suppliers are involved in the product/service
development process.. ... . 0 1 2 3 4

27 Long-term relationships are developed
with suppliers.... .... 0 1 2 3 4

28. There is reliance on a few dependable
suppliers. 0 1 2 3 4

Please indicate the extent to which the following statements are true of the **supervisors** in your primary place of employment.

29. Supervisors are trained in statistical
improvement techniques. 0 1 2 3 4

30. Supervisors help their employees on the job.. 0 1 2 3 4

31. Supervisors work to build the trust of their employees. 0 1 2 3 4

32 Supervisors lead in a way that is consistent with the aims of the organization........... 0 1 2 3 4

33 Supervisors are viewed as coaches by their employees.... .... 0 1 2 3 4

Please indicate the extent to which the following **practices** are true in primary place of employment.

34 Performance appraisals are used to rank employees 0 1 2 3 4

35. Statistical control techniques are used to minimize reliance on mass inspection 0 1 2 3 4

36 Customers' requirements are analyzed in the process of developing a product/service .. . 0 1 2 3 4

37 Work standards are set based on process capability studies 0 1 2 3 4

38 Customers' feedback is used to continually improve the product/service. 0 1 2 3 4

39 Different departments have compatible goals . 0 1 2 3 4

40 In the product/service design process there is teamwork between different departments.. . 0 1 2 3 4

41. Numerical quotas are given higher priority than quality of workmanship. 0 1 2 3 4

42 There is good communications between different departments. 0 1 2 3 4

43. Work standards are based on both quality and quantity rather than quantity only... .. 0 1 2 3 4

44 The quality of the working environment is poor 0 1 2 3 4

45 There are programs to develop effective communications between employees..... . .. . 0 1 2 3 4

46. There is inadequate documentation on how to do the job 0 1 2 3 4

47 There are programs to develop team-work between employees.. .... 0 1 2 3 4

48 There are programs to develop employees' conflict resolution skills 0 1 2 3 4

49 There is pressure for short term results... . 0 1 2 3 4

50 There are programs to broaden employees' skills for future organizational needs.. .... 0 1 2 3 4

Pertaining to your primary place of employment, please answer the following questions relative to your largest **competitors**.

51 Your customers' **retention rate** compared to the competition is:

Inferior	Below Average	Equal To The Competition	Better Than Average	Superior
___	___	___	___	___
1	2	3	4	5

52. The **features** of your product(s)/service(s) compared to the competition are

Inferior	Below Average	Equal To The Competition	Better Than Average	Superior
___	___	___	___	___
1	2	3	4	5

53 The extent of your **advertising/promotion** expenditures relative to the competition is

Much Lower	Somewhat Lower	Same As The Competition	Somewhat Higher	Much Higher
___	___	___	___	___
1	2	3	4	5

54 The **breadth** of your product line (e g., number of products/services offered) relative to the competition is

Less Broad Than The Competition		Same As The Competition		Much Broader Than The Competition
___	___	___	___	___
1	2	3	4	5

Please answer the following questions about **your organization** in your primary place of employment

55 How often does your organization have to **repeat work** because it was not done correctly the first time?

Never	Seldom	Sometimes	Often	Always
___	___	___	___	___
1	2	3	4	5

56 To what degree is the production or service process **standardized** to reduce defects or errors?

Not At All Standardized	Somewhat Standardized	Moderately Standardized	Mostly Standardized	Very Highly Standardized
___	___	___	___	___
1	2	3	4	5

APPENDIX B

DERIVATION OF THE Σ MATRIX

$$\eta=\Gamma\xi+\zeta \tag{B1}$$

$$x=\Lambda_x\xi+\delta \tag{B2}$$

$$y=\Lambda_y\eta+\epsilon \tag{B3}$$

The Σ matrix is defined as

$$\Sigma = \left[\begin{array}{c|c} E(yy') & E(yx') \\ \hline E(xy') & E(xx') \end{array}\right] \tag{B4}$$

where, by (B3)

$$\begin{aligned} E(yy') &= E[(\Lambda_y\eta+\epsilon)(\Lambda_y\eta+\epsilon)'] \\ &= E[\Lambda_y\eta\eta'\Lambda_y'+\Lambda_y\eta\epsilon'+\epsilon\eta'\Lambda_y'+\epsilon\epsilon'] \\ &= \Lambda_yE(\eta\eta')\Lambda_y'+\Lambda_yE(\eta\epsilon')+E(\eta\epsilon')\Lambda_y+E(\epsilon\epsilon') \end{aligned}$$

Since we assume $E(\eta\epsilon')=0$, the 2nd and 3rd terms vanish, and upon substituting (B1):

$$\begin{aligned} E(yy') &= \Lambda_yE[(\Gamma\xi+\zeta)(\Gamma\xi+\zeta)']\Lambda_y'+E(\epsilon\epsilon') \\ &=\Lambda_y[\Gamma E(\xi\xi')\Gamma'+E(\Gamma\xi\zeta'+\zeta\xi'\Gamma')+E(\zeta\zeta')]\Lambda_y'+E(\epsilon\epsilon') \end{aligned}$$

Since $E(\xi\zeta')=0$, this reduces to

$$\begin{aligned} E(yy') &= \Lambda_y(\Gamma E(\xi\xi')\Gamma'+E(\zeta\zeta'))\Lambda_y'+E(\epsilon\epsilon') \\ &= \Lambda_y(\Gamma\Phi\Gamma'+\Psi)\Lambda_y'+\theta_\epsilon \end{aligned} \tag{B5}$$

Similarly, by (B2) and (B3)

$$\begin{aligned} E(xy') &= E[(\Lambda_x\xi+\delta)(\Lambda_y\eta+\epsilon')] \\ &= E[\Lambda_x\xi\eta'\Lambda_y'+\delta\eta'\Lambda_y'+\Lambda_x\xi\epsilon'+\delta\epsilon'] \\ &=\Lambda_xE(\xi\eta')\Lambda_y'+E(\delta\eta')\Lambda_y'+\Lambda_xE(\xi\epsilon')+E(\delta\epsilon') \end{aligned}$$

Since $E(\delta\eta')=E(\xi\epsilon')=E(\delta\epsilon')=0$, this reduces to

$$= \Lambda_x E(\xi\eta')\Lambda_y'$$

By substituting (B1), this can be expressed as

$$= \Lambda_x E[\xi(\Gamma\xi+\zeta')]\Lambda_y'$$

$$= \Lambda_x E[\xi\xi'\Gamma'+\xi\zeta']\Lambda_y'$$

$$= \Lambda_x [E(\xi\xi')\Gamma'+E(\xi\zeta')]\Lambda_y'$$

Since $E(\xi\zeta')=0$, this reduces to

$$= \Lambda_x\Phi\Gamma'\Lambda_y' \qquad \text{(B6)}$$

Taking the transpose of (B6)

$$E(yx') = \Lambda_y\Gamma\Phi'\Lambda_x' \qquad \text{(B7)}$$

Similarly, by (B2)

$$E(xx') = E[(\Lambda_x\xi+\delta)(\Lambda_x\xi+\delta)']$$

$$=\Lambda_x E(\xi\xi')\Lambda_x'+E(\delta\xi')\Lambda_x'+\Lambda_x E(\xi\delta')+E(\delta\delta')$$

Since $E(\delta\xi')=0$, this reduces to

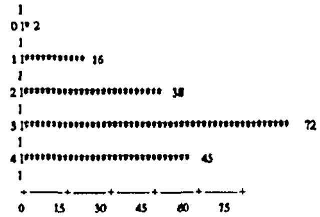
$$= \Lambda_x\Phi\Lambda_x'+\theta_\delta \qquad \text{(B8)}$$

Thus:

$$\Sigma = \left[\begin{array}{c|c} \Lambda_y(\Gamma\Phi\Gamma'+\Psi)\Lambda_y'+\theta_\epsilon & \Lambda_y\Gamma\Phi'\Lambda_x' \\ \hline \Lambda_x\Phi\Gamma'\Lambda_y' & \Lambda_x\Phi\Lambda_x'+\theta_\delta \end{array}\right] \qquad \text{(B9)}$$

APPENDIX C

HISTOGRAMS OF OBSERVED VARIABLES



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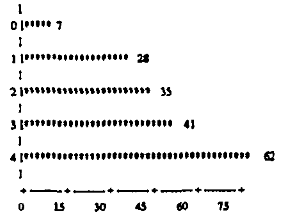

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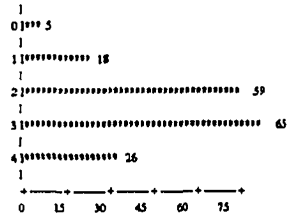
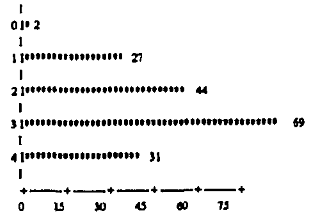
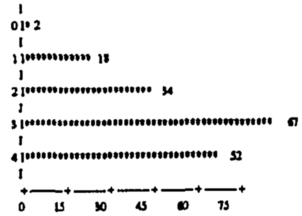


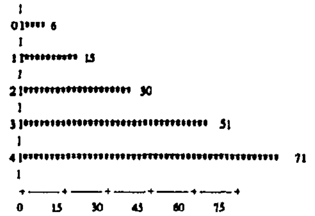
Frequency (X3)



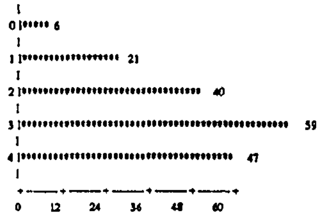
Frequency (X4)



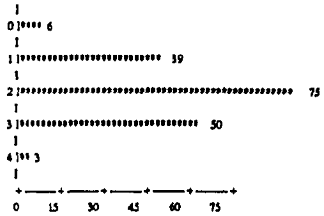
Frequency (X5)



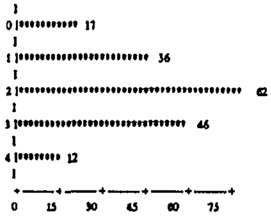
Frequency (X6)



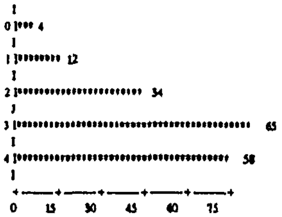
Frequency (X7)



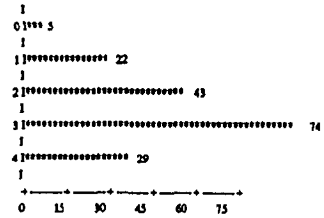
Frequency (X8)



Frequency (X9)



Frequency (X10)



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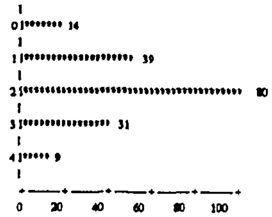

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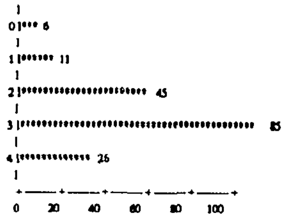
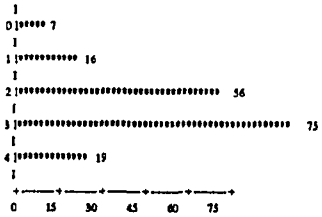


Frequency (X13)



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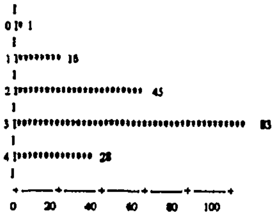
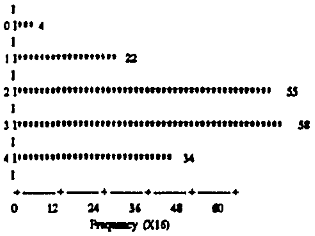


Frequency (X15)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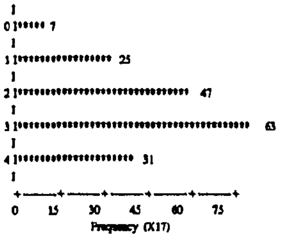
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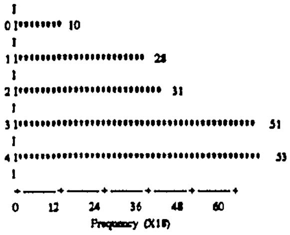
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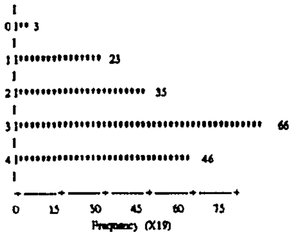
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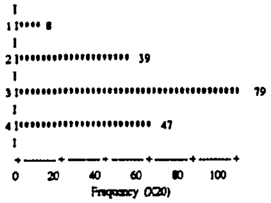
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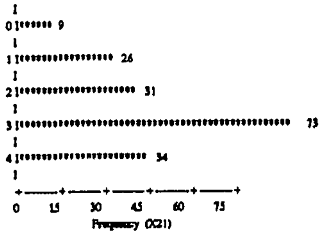
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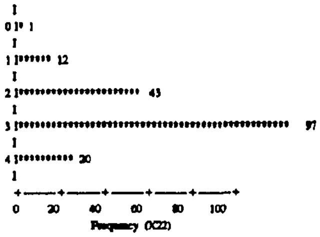
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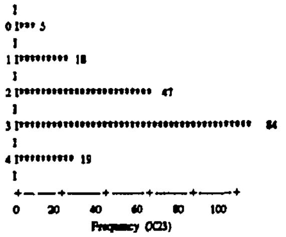
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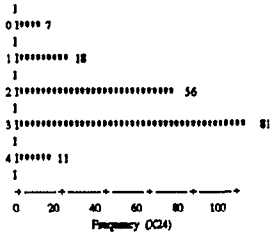
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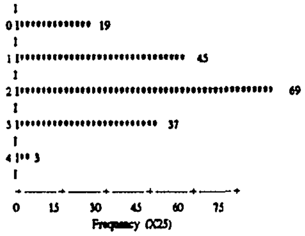
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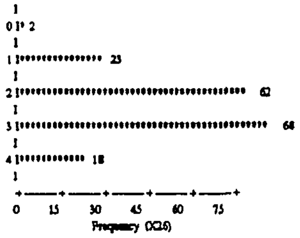
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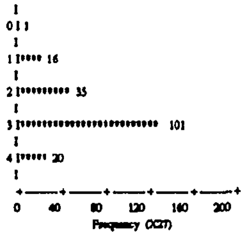
3 68
4 18
0 15 30 45 60 75
Frequency (X26)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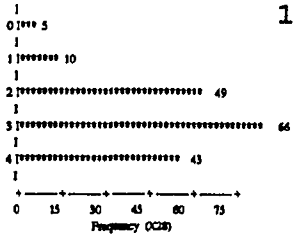
Frequency (X27)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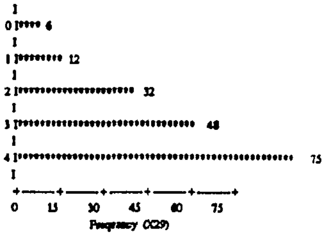
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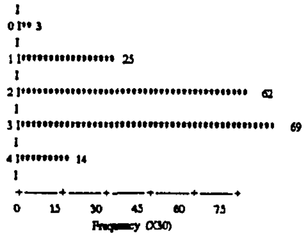
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2 62
3 69
4 14
0 15 30 45 60 75
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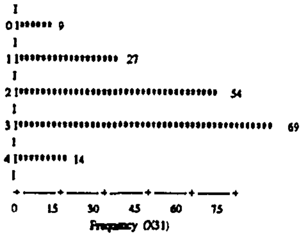
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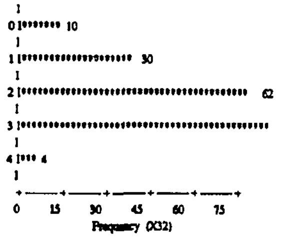
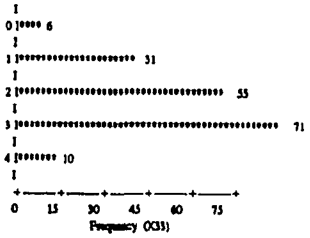
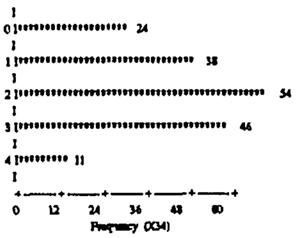
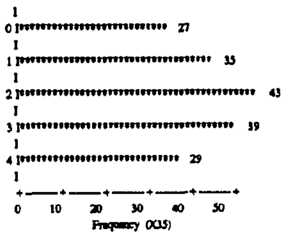
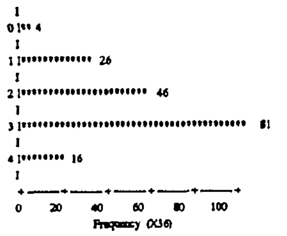
2 54
3 69
4 14
0 15 30 45 60 75
Frequency (X31)

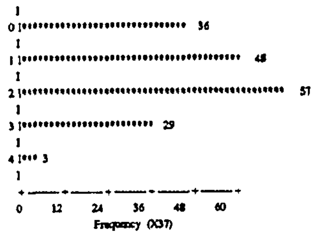

0 10
1 30
2 62
3 67
4 4
0 15 30 45 60 75
Frequency (X32)

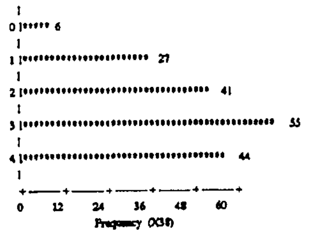

0 6
1 31
2 55
3 71
4 10
0 15 30 45 60 75
Frequency (X33)

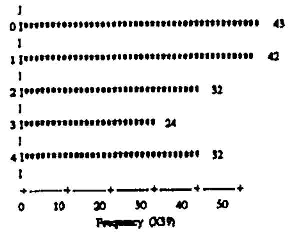

0 24
1 38
2 54
3 46
4 11
0 12 24 36 48 60
Frequency (X34)

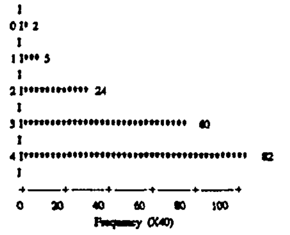

0 27
1 35
2 43
3 39
4 29
0 10 20 30 40 50
Frequency (X35)

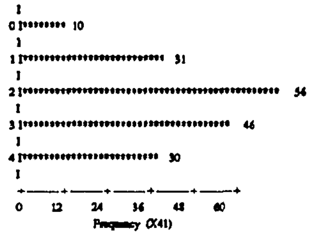

0 4
1 26
2 46
3 81
4 16
0 20 40 60 80 100
Frequency (X36)

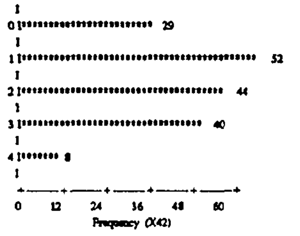

0 36
1 48
2 57
3 29
4 3
0 12 24 36 48 60
Frequency (X37)

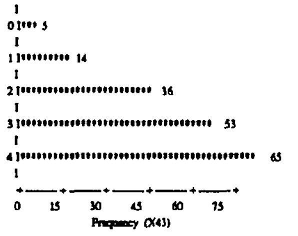

0 6
1 27
2 41
3 55
4 44
0 12 24 36 48 60
Frequency (X38)

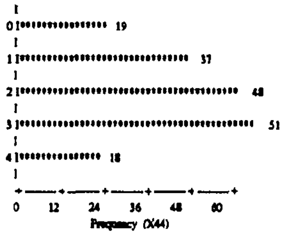

0 43
1 42
2 32
3 24
4 32
0 10 20 30 40 50
Frequency (X39)

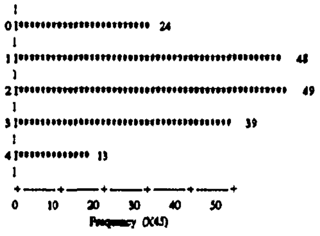

0 2
1 5
2 24
3 60
4 82
0 20 40 60 80 100
Frequency (X40)

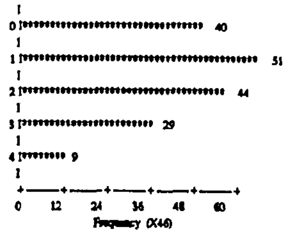

0 10
1 31
2 54
3 46
4 30
0 12 24 36 48 60
Frequency (X41)

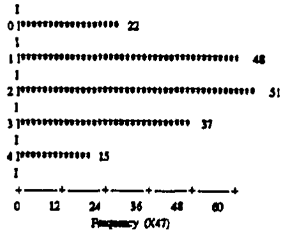

0 29
1 52
2 44
3 40
4 8
0 12 24 36 48 60
Frequency (X42)

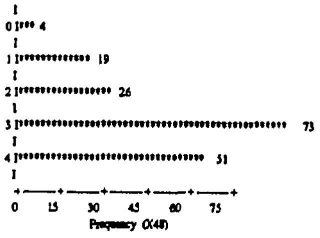

0 5
1 14
2 36
3 53
4 65
0 15 30 45 60 75
Frequency (X43)

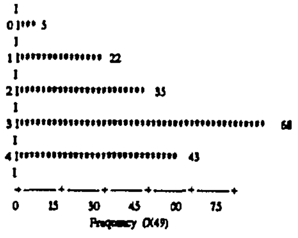

0 19
1 37
2 48
3 51
4 18
0 12 24 36 48 60
Frequency (X44)

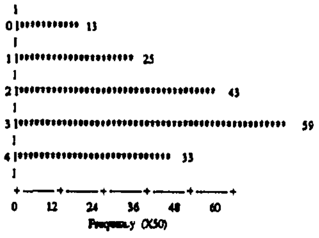

0 24
1 48
2 49
3 39
4 13
0 10 20 30 40 50
Frequency (X45)

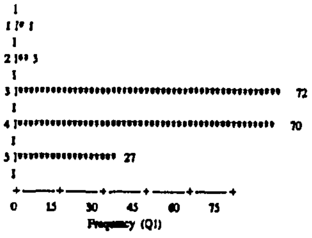

0 40
1 51
2 44
3 29
4 9
0 12 24 36 48 60
Frequency (X46)


0 22
1 48
2 51
3 37
4 15
0 12 24 36 48 60
Frequency (X47)


0 4
1 19
2 26
3 73
4 51
0 15 30 45 60 75
Frequency (X48)


0 5
1 22
2 35
3 68
4 43
0 15 30 45 60 75
Frequency (X49)


0 13
1 25
2 43
3 59
4 33
0 12 24 36 48 60
Frequency (X50)


1 1
2 3
3 72
4 70
5 27
0 15 30 45 60 75
Frequency (Q1)

```
  |
2 |*** 6
  |
3 |*********************** 45
  |
4 |*********************************************  89
  |
5 |***************** 33
  |
  +------+------+------+------+------+------+
  0     20     40     60     80    100
              Frequency (Q2)

  |
1 |* 1
  |
2 |************** 28
  |
3 |*********************************************  89
  |
4 |*************************** 53
  |
5 |* 2
  |
  +------+------+------+------+------+------+
  0     20     40     60     80    100
              Frequency (Q3)
```

APPENDIX D

INTERNAL CONSISTENCY OF SCALES

```
                    S C A L E   (F A C T O R 1)

                    MEAN       STD DEV      CASES

 1     X1           2 8208        9628      173.0
 2     X2           2.7110      1 2237       173.0
 3     X3           2 5145        9681      173 0
 4     X4           2 5780       .9947      173.0

               CORRELATION MATRIX
               X1         X2         X3         X4

X1             1 0000
X2               2173     1 0000
X3              .4300       4992     1.0000
X4               4305      .2192      .3173     1 0000

     # OF CASES =       173 0

ITEM MEANS          MEAN    MINIMUM    MAXIMUM     RANGE   MAX/MIN  VARIANCE
                    2 6561   2 5145     2 8208      .3064   1.1218      0188

INTER-ITEM
CORRELATIONS        MEAN    MINIMUM    MAXIMUM     RANGE   MAX/MIN  VARIANCE
                    .3523     2173       .4992      .2819     2.2970    0129

ITEM-TOTAL STATISTICS:

          SCALE       SCALE     CORRECTED
          MEAN      VARIANCE      ITEM-       SQUARED        ALPHA
          IF ITEM   IF ITEM       TOTAL       MULTIPLE       IF ITEM
          DELETED   DELETED   CORRELATION   CORRELATION     DELETED

X1         7.8035    5.7518       .4630         .2815         .6070
X2         7.9133    5.0913       .4036         .2537         .6592
X3         8.1098    5.2844       .5832         .3655         .5309
X4         8 0462    5.8583       .4090         .2115         .6393

RELIABILITY COEFFICIENTS     4 ITEMS

ALPHA =   .6754         STANDARDIZED ITEM ALPHA =    6851
```

```
                    S C A L E   (F A C T O R 2)

  1      X5
  2      X6
  3.     X7

                         MEAN        STD DEV      CASES

  1      X5              2 8613      1.0019      173 0
  2      X6              2 9595      1 1173      173 0
  3      X7              2 6936      1 1017      173 0

                    CORRELATION MATRIX
                    X5          X6          X7

X5                 1 0000
X6                   3273       1 0000
X7                  .6565        .4102      1 0000

      # OF CASES =         173 0

ITEM MEANS             MEAN     MINIMUM     MAXIMUM      RANGE     MAX/MIN   VARIANCE
                      2 8382    2.6936      2.9595        .2659    1 0987       0181

INTER-ITEM
CORRELATIONS            MEAN     MINIMUM     MAXIMUM      RANGE     MAX/MIN   VARIANCE
                        .4647     3273         6565        .3292    2 0056       0235

ITEM-TOTAL STATISTICS

              SCALE       SCALE      CORRECTED
              MEAN        VARIANCE     ITEM-        SQUARED        ALPHA
              IF ITEM     IF ITEM      TOTAL        MULTIPLE       IF ITEM
              DELETED     DELETED    CORRELATION   CORRELATION    DELETED

X5             5 6532      3 4720        5844          4351          .5818
X6             5 5549      3 6670        4073          .1742         .7905
X7             5 8208      2 9851        .6460         4738          .4910

RELIABILITY COEFFICIENTS      3 ITEMS

ALPHA =     7192          STANDARDIZED ITEM ALPHA =    .7226
```

```
                      S C A L E   (F A C T O R 3)

  1    X8
  2.   X9
  3    X10

                          MEAN        STD DEV      CASES

  1    X8                 2.0289        .8520      173.0
  2.   X9                 2 0000       1 0729      173.0
  3    X10                2 9306       1 0092      173.0

                 CORRELATION MATRIX
                 X8          X9          X10

X8              1 0000
X9                3434       1 0000
X10               1714         3651      1 0000

     # OF CASES =        173 0

ITEM MEANS          MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                    2 3198   2 0000     2.9306       .9306    1.4653      2800

INTER-ITEM
CORRELATIONS         MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                     .2933    1714       3651         1937    2 1304      0090

ITEM-TOTAL STATISTICS


            SCALE       SCALE     CORRECTED
            MEAN       VARIANCE     ITEM-       SQUARED        ALPHA
            IF ITEM    IF ITEM      TOTAL       MULTIPLE      IF ITEM
            DELETED    DELETED   CORRELATION  CORRELATION    DELETED

X8           4 9306     2.9603      .3147         .1204          .5342
X9           4 9595     2 0391       4630         .2146          .2891
X10          4 0289      2.5050     .3398         .1357          .5013

RELIABILITY COEFFICIENTS      3 ITEMS

ALPHA =    .5576          STANDARDIZED ITEM ALPHA =    .5546
```

```
                    S C A L E   (F A C T O R 4)

   1     X11
   2     X12
   3     X13
   4     X14

                         MEAN       STD DEV      CASES

   1     X11             2 5780      1.0064      173.0
   2     X12             1 8960        9649      173 0
   3     X13             2 6590        9304      173 0
   4     X14             2.4798       .9498      173 0

                    CORRELATION MATRIX
                   X11         X12         X13         X14

  X11              1 0000
  X12               5473       1.0000
  X13               5906         4784      1 0000
  X14               2738         2641       .5283      1 0000

        # OF CASES =      173 0

  ITEM MEANS             MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                         2 4032   1.8960     2.6590       7630     1 4024      1197

  INTER-ITEM
  CORRELATIONS            MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                          4471     2641       .5906        3264     2 2359      0185

 ITEM-TOTAL STATISTICS


              SCALE       SCALE     CORRECTED
              MEAN       VARIANCE     ITEM-       SQUARED        ALPHA
              IF ITEM    IF ITEM      TOTAL       MULTIPLE       IF ITEM
              DELETED    DELETED   CORRELATION  CORRELATION     DELETED

  X11          7.0347     4 9755      5997          .4421          6864
  X12          7 7168     5.3437      5393          .3375          .7195
  X13          6 9538     4 9165      7025          .5117          6317
  X14          7.1329     5.8369      .4230         .2825          .7780

  RELIABILITY COEFFICIENTS     4 ITEMS

 ALPHA =   .7632          STANDARDIZED ITEM ALPHA =   .7638
```

```
                    S C A L E   (F A C T O R 5)

 1     X15
 2     X16
 3     X17

                    MEAN       STD DEV      CASES

 1.    X15          2 6994      .8706      173.0
 2     X16          2 5549     1 0194      173.0
 3     X17          2.4971     1 0709      173 0

               CORRELATION MATRIX
               X15         X16        X17

X15            1 0000
X16             6411       1 0000
X17            .2423        3157      1 0000

      # OF CASES =       173.0

ITEM MEANS          MEAN    MINIMUM    MAXIMUM     RANGE    MAX/MIN   VARIANCE
                    2.5838   2 4971     2 6994      .2023    1 0810     0109

INTER-ITEM
CORRELATIONS        MEAN    MINIMUM    MAXIMUM     RANGE    MAX/MIN   VARIANCE
                     3997    .2423       6411       3988     2 6461     0360

ITEM-TOTAL STATISTICS


             SCALE      SCALE     CORRECTED
             MEAN      VARIANCE     ITEM-       SQUARED        ALPHA
             IF ITEM   IF ITEM      TOTAL       MULTIPLE      IF ITEM
             DELETED   DELETED   CORRELATION  CORRELATION     DELETED

X15           5 0520    2.8752       5384         4127          .4795
X16           5 1965    2 3565       5838        .4383          .3834
X17           5 2543    2.9349       3110        .1024          .7754

RELIABILITY COEFFICIENTS     3 ITEMS

ALPHA =    6545         STANDARDIZED ITEM ALPHA =    6664
```

```
                    S C A L E   (F A C T O R 6)

  1    X18
  2    X19
  3    X20
  4    X21

                         MEAN       STD DEV     CASES

  1    X18              2.6301      1.2350     173.0
  2.   X19              2 7457      1 0477     173 0
  3    X20              2.9538       .8270     173.0
  4    X21              2 5607      1.1122     173 0

                 CORRELATION MATRIX
                 X18        X19        X20        X21

X18              1 0000
X19               .3088     1 0000
X20               0629       .2749     1.0000
X21               .4652      .4483      .1471     1 0000

     # OF CASES =       173 0

ITEM MEANS          MEAN   MINIMUM   MAXIMUM    RANGE   MAX/MIN  VARIANCE
                   2 7225   2 5607    2 9538     3931   1 1535     .0296

INTER-ITEM
CORRELATIONS        MEAN   MINIMUM   MAXIMUM    RANGE   MAX/MIN  VARIANCE
                    2845    0629      4652       4023    7 4012     0233

ITEM-TOTAL STATISTICS


          SCALE       SCALE     CORRECTED
          MEAN       VARIANCE     ITEM-       SQUARED       ALPHA
          IF ITEM    IF ITEM      TOTAL       MULTIPLE      IF ITEM
          DELETED    DELETED   CORRELATION  CORRELATION    DELETED

X18        8.2601     4 8447      4078         .2301         .5585
X19        8 1445     5 1592      .4895        .2588         .4916
X20        7 9364     7.0250      .2002        .0776         .6711
X21        8 3295     4.7106      .5372         3201         .4470


RELIABILITY COEFFICIENTS     4 ITEMS

ALPHA =    6243          STANDARDIZED ITEM ALPHA =   .6140
```

```
                    S C A L E   (F A C T O R 7)

     1     X22
     2     X23
     3     X24
     4     X25

                         MEAN       STD DEV      CASES

     1     X22          2.7110        7834       173.0
     2     X23          2.5434        9242       173.0
     3     X24          2 4104        9082       173.0
     4     X25          1 7688        .9667      173 0

                    CORRELATION MATRIX
                  X22          X23          X24          X25

  X22            1 0000
  X23             6277        1 0000
  X24             4701         7233        1 0000
  X25             4870         6750         .6318        1.0000

         # OF CASES =        173.0

  ITEM MEANS.            MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                        2 3584   1 7688      2 7110       .9422    1 5327      1696

  INTER-ITEM
  CORRELATIONS           MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                         .6025    4701        7233        2532     1.5387      0095

 ITEM-TOTAL STATISTICS

             SCALE       SCALE      CORRECTED
             MEAN       VARIANCE     ITEM-        SQUARED        ALPHA
             IF ITEM    IF ITEM      TOTAL        MULTIPLE       IF ITEM
             DELETED    DELETED   CORRELATION   CORRELATION     DELETED

  X22         6 7225     6 1435       5963          .4014          .8619
  X23         6 8902     4.8890       8146           6688          .7719
  X24         7.0231     5 2553       .7187          .5610          .8143
  X25         7 6647     5.0846       .7003           5045           8237

  RELIABILITY COEFFICIENTS     4 ITEMS

  ALPHA =    8590         STANDARDIZED ITEM ALPHA =   .8584
```

```
                    S C A L E  (F A C T O R 8)

  1     X26
  2     X27
  3     X28
  4     X29

                        MEAN      STD DEV     CASES

  1     X26             2 4451      .8916     173 0
  2     X27             2 7110       8125     173.0
  3     X28             2.7630      .9862     173 0
  4.    X29             3.0058     1 1023     173 0

                  CORRELATION MATRIX
                 X26        X27        X28        X29

X26             1 0000
X27              3712      1 0000
X28              4380       3711      1 0000
X29              1867       1317      .2740      1 0000

        # OF CASES =       173.0

ITEM MEANS·          MEAN    MINIMUM    MAXIMUM     RANGE    MAX/MIN   VARIANCE
                    2 7312   2 4451      3.0058      5607    1 2293      0529

INTER-ITEM
CORRELATIONS          MEAN    MINIMUM    MAXIMUM     RANGE    MAX/MIN   VARIANCE
                      2955     1317       .4380      3063    3 3260      0129

ITEM-TOTAL STATISTICS

              SCALE      SCALE      CORRECTED
              MEAN       VARIANCE   ITEM-       SQUARED       ALPHA
              IF ITEM    IF ITEM    TOTAL       MULTIPLE      IF ITEM
              DELETED    DELETED    CORRELATION CORRELATION   DELETED

X26           8 4798     4 2743      4544        .2462         .5006
X27           8 2139     4.7156     .3878        .1918         .5513
X28           8 1618     3 8109     .5093        .2750          4490
X29           7 9191     4 3306     .2613        .0808         .6591

RELIABILITY COEFFICIENTS      4 ITEMS

ALPHA =    6132          STANDARDIZED ITEM ALPHA =    6265
```

```
                        S C A L E   (F A C T O R 9)

  1     X30
  2     X31
  3     X32

                        MEAN        STD DEV      CASES

  1     X30             2.3815        8919       173.0
  2.    X31             2.3006       1 0011       173.0
  3     X32             2 1445        .9319      173 0

                    CORRELATION MATRIX
                   X30         X31         X32

X30               1 0000
X31                 4959       1 0000
X32                 4369        .6262      1.0000

      # OF CASES =        173 0

ITEM MEANS.             MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                        2 2755   2 1445     2 3815       2370     1 1105     0145

INTER-ITEM
CORRELATIONS             MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                         5197     4369       6262        .1893    1.4333      0075

ITEM-TOTAL STATISTICS·

            SCALE      SCALE     CORRECTED
            MEAN      VARIANCE     ITEM-       SQUARED        ALPHA
            IF ITEM   IF ITEM      TOTAL       MULTIPLE       IF ITEM
            DELETED   DELETED   CORRELATION  CORRELATION     DELETED

X30          4 4451    3 0391      5184         2722          .7689
X31          4 5260    2.3903      6636         .4532         .6077
X32          4 6821    2 6832      6206         .4133         .6601

RELIABILITY COEFFICIENTS     3 ITEMS

ALPHA =    7657         STANDARDIZED ITEM ALPHA =   .7645
```

```
                  S C A L E   (F A C T O R 1 0)

   1     X33
   2     X34
   3     X35

                        MEAN        STD DEV      CASES

   1     X33            2 2775        9422      173 0
   2     X34            1.8960      1.1364      173.0
   3     X35            2.0462      1.3154      173.0

                   CORRELATION MATRIX
                  X33         X34         X35

X33              1 0000
X34               .1466      1 0000
X35               .3555       .0110      1 0000

      # OF CASES =       173 0

ITEM MEANS:         MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                    2 0732   1 8960     2 2775       3815     1 2012      0369

INTER-ITEM
CORRELATIONS         MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                     1710     0110       3555        .3445    32 2711     .0241

ITEM-TOTAL STATISTICS


           SCALE      SCALE     CORRECTED
           MEAN       VARIANCE    ITEM-       SQUARED        ALPHA
           IF ITEM    IF ITEM     TOTAL       MULTIPLE       IF ITEM
           DELETED    DELETED   CORRELATION  CORRELATION    DELETED

X33         3 9422     3.0548      3629         1467          0216
X34         4.3237     3 4993      .0816        .0234         5036
X35         4 1734     2 4930      2201         1281          2518

RELIABILITY COEFFICIENTS     3 ITEMS

ALPHA =    3585         STANDARDIZED ITEM ALPHA =   .3823
```

```
                    S C A L E   (F A C T O R 1 1)

  1     X36
  2     X37
  3     X38

                        MEAN        STD DEV      CASES

  1     X36             2 4566        9367      173.0
  2     X37             1 5087      1.0544      173.0
  3     X38             2 6012      1.1296      173 0

                  CORRELATION MATRIX
                 X36         X37         X38

X36              1 0000
X37               .3285      1 0000
X38               4643        2104       1 0000

      # OF CASES =       173 0

ITEM MEANS·       MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                 2.1888    1 5087     2.6012      1 0925    1 7241      3522

INTER-ITEM
CORRELATIONS       MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                   3344     .2104       4643        .2540    2.2072      0129

ITEM-TOTAL STATISTICS

            SCALE       SCALE      CORRECTED
            MEAN        VARIANCE     ITEM-        SQUARED        ALPHA
            IF ITEM     IF ITEM      TOTAL        MULTIPLE       IF ITEM
            DELETED     DELETED    CORRELATION    CORRELATION    DELETED

X36          4 1098      2 8890      5124           .2714          3469
X37          5 0578      3 1362      3080            1122         .6267
X38          3 9653      2 6383      4043           .2193         .4920

RELIABILITY COEFFICIENTS      3 ITEMS

ALPHA =     5926          STANDARDIZED ITEM ALPHA =    .6012
```

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                    S C A L E   (F A C T O R 1 2)

   1.    X39
   2     X40
   3     X41
   4     X42
   5     X43

                        MEAN       STD DEV      CASES

   1     X39            1 7688      1.4402     173.0
   2     X40            3.2428       .8820     173.0
   3     X41            2.3179      1 1297     173 0
   4     X42            1.6879      1 1390     173.0
   5     X43            2 9191      1.0807     173.0

                   CORRELATION MATRIX
                   X39         X40        X41        X42        X43

 X39              1 0000
 X40               .0033      1 0000
 X41              - 0153       1205      1.0000
 X42               0231        2379       .3035     1 0000
 X43               0664        1000       1069       3572      1 0000

        # OF CASES =       173 0

 ITEM MEANS.        MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                   2.3873    1.6879     3.2428       1.5549    1 9212      4728

 INTER-ITEM
 CORRELATIONS·       MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                     1303    - 0153      3572         3725  -   23 3394     0155

 ITEM-TOTAL STATISTICS·

            SCALE      SCALE     CORRECTED
            MEAN       VARIANCE    ITEM-       SQUARED        ALPHA
            IF ITEM    IF ITEM     TOTAL       MULTIPLE       IF ITEM
            DELETED    DELETED   CORRELATION  CORRELATION     DELETED

 X39        10.1676     7.3496      .0308        .0050          5135
 X40         8.6936     7 9696      .1842        .0594          .3604
 X41         9 6185     7.1559      2039         .0951          .3426
 X42        10.2486     6.1530      .3918        .2293          .1857
 X43         9.0173     6.9590      .2697        1312           .2938

 RELIABILITY COEFFICIENTS      5 ITEMS

 ALPHA =    .3972          STANDARDIZED ITEM ALPHA =    .4284
```

```
                    S C A L E   (F A C T O R 1 3)

   1     X44
   2     X45
   3     X46
   4.    X47

                     MEAN      STD DEV     CASES

   1     X44         2.0694     1.1693     173 0
   2     X45         1.8208     1.1550     173 0
   3     X46         1 5145     1 1694     173 0
   4     X47         1.8555     1 1548     173.0

                CORRELATION MATRIX
               X44        X45        X46        X47

X44            1 0000
X45              6679     1 0000
X46              6838       5551     1 0000
X47              5026       5079       4945     1.0000

     # OF CASES =      173 0

ITEM MEANS          MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                    1 8150   1 5145     2 0694       .5549    1 3664     0522

INTER-ITEM
CORRELATIONS         MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                     5686     4945       6838         1893    1.3829     .0067

ITEM-TOTAL STATISTICS

            SCALE      SCALE     CORRECTED
            MEAN       VARIANCE    ITEM-       SQUARED        ALPHA
            IF ITEM    IF ITEM     TOTAL       MULTIPLE       IF ITEM
            DELETED    DELETED   CORRELATION  CORRELATION     DELETED

X44          5 1908     8 2250     .7502         5944          .7641
X45          5 4393     8 6315     .6864        .4938          .7930
X46          5.7457     8.5512     .6879        .5059          .7922
X47          5.4046     9 2423     .5765         3342           8397

RELIABILITY COEFFICIENTS      4 ITEMS

ALPHA =   .8408          STANDARDIZED ITEM ALPHA =   .8406
```

```
                SCALE (FACTOR14)

 1    X48
 2    X49
 3    X50

                MEAN      STD DEV     CASES

 1    X48       2 8555    1.0382     173 0
 2    X49       2.7052    1.0674     173.0
 3.   X50       2 4277    1.1722     173.0

            CORRELATION MATRIX
           X48       X49       X50

X48        1 0000
X49          4178    1.0000
X50          2326      2919    1 0000

     # OF CASES =     173 0

ITEM MEANS.        MEAN    MINIMUM   MAXIMUM    RANGE   MAX/MIN  VARIANCE
                   2 6628  2 4277    2.8555      4277   1 1762    .0471

INTER-ITEM
CORRELATIONS        MEAN   MINIMUM   MAXIMUM    RANGE   MAX/MIN  VARIANCE
                    3141   .2326     4178        .1852  1 7959    .0072

ITEM-TOTAL STATISTICS

         SCALE     SCALE     CORRECTED
         MEAN      VARIANCE    ITEM-       SQUARED      ALPHA
         IF ITEM   IF ITEM     TOTAL       MULTIPLE     IF ITEM
         DELETED   DELETED   CORRELATION  CORRELATION   DELETED

X48       5 1329    3.2438     3990         .1879        .4503
X49       5 2832    3 0181     4466         .2146         3752
X50       5 5607    3 1431     3120         .1000        .5892

RELIABILITY COEFFICIENTS     3 ITEMS

ALPHA =    5734         STANDARDIZED ITEM ALPHA =   .5787
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```
                    S C A L E  (Q U A L I T Y)

  1     Q1
  2     Q2
  3     Q3

                    MEAN      STD DEV     CASES

  1.    Q1          3.6879      .7744     173 0
  2     Q2          3 8613       7574     173 0
  3     Q3          3.1561      .7185     173.0

                CORRELATION MATRIX
                Q1        Q2        Q3

 Q1             1 0000
 Q2              4610     1 0000
 Q3             .3284      2858     1 0000

       # OF CASES =      173.0

 ITEM MEANS          MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                     3 5684   3 1561     3.8613       7052     1 2234     .1350

 INTER-ITEM
 CORRELATIONS         MEAN    MINIMUM    MAXIMUM      RANGE    MAX/MIN   VARIANCE
                      3584     2858        4610       .1753    1 6134      0067

 ITEM-TOTAL STATISTICS.

          SCALE      SCALE     CORRECTED
          MEAN      VARIANCE     ITEM-       SQUARED       ALPHA
          IF ITEM   IF ITEM      TOTAL       MULTIPLE      IF ITEM
          DELETED   DELETED   CORRELATION  CORRELATION    DELETED

 Q1        7.0173    1 4009      .4944         .2547         .4440
 Q2        6 8439    1.4813       4620          2328         .4934
 Q3        7 5491    1 7141      .3596         .1308         .6310

 RELIABILITY COEFFICIENTS      3 ITEMS

 ALPHA =    6281         STANDARDIZED ITEM ALPHA =    .6263
```

APPENDIX E

POLYCHORIC CORRELATIONS OF OBSERVED VARIABLES

	VAR 1	VAR 2	VAR 3	VAR 4	VAR 5	VAR 6
VAR 1	1.000					
VAR 2	0.239	1.000				
VAR 3	0.477	0.567	1.000			
VAR 4	0.483	0.252	0.363	1.000		
VAR 5	0.573	0.280	0.389	0.533	1.000	
VAR 6	0.391	0.131	0.136	0.250	0.418	1.000
VAR 7	0.597	0.310	0.382	0.515	0.725	0.499
VAR 8	0.439	0.335	0.392	0.446	0.558	0.431
VAR 9	0.357	0.118	0.299	0.297	0.411	0.136
VAR 10	0.186	0.198	0.155	0.123	0.091	0.146
VAR 11	0.415	0.324	0.383	0.557	0.420	0.109
VAR 12	0.482	0.219	0.289	0.426	0.520	0.386
VAR 13	0.225	0.291	0.301	0.170	0.409	0.224
VAR 14	0.377	0.187	0.192	0.358	0.470	0.510
VAR 15	0.010	-0.024	-0.012	0.143	0.039	0.076
VAR 16	0.288	0.236	0.441	0.337	0.311	0.260
VAR 17	0.384	0.186	0.240	0.381	0.352	0.157
VAR 18	0.098	0.165	0.084	0.185	0.217	0.274
VAR 19	0.367	0.197	0.216	0.365	0.328	0.139
VAR 20	0.163	0.103	0.144	0.188	0.105	0.217
VAR 21	0.401	0.210	0.316	0.266	0.367	0.295
VAR 22	0.295	0.221	0.267	0.159	0.296	0.258
VAR 23	0.284	0.078	0.077	0.218	0.290	0.176
VAR 24	0.139	0.120	0.131	0.199	0.069	0.164
VAR 25	0.218	0.140	0.148	0.205	0.168	0.329
VAR 26	0.031	0.076	0.137	0.139	0.109	0.118
VAR 27	0.145	0.059	-0.001	0.150	0.206	0.285
VAR 28	0.024	0.077	-0.003	0.050	-0.041	0.036
VAR 29	0.242	0.092	0.136	0.221	0.174	0.138
VAR 30	0.336	0.322	0.327	0.383	0.354	0.250
VAR 31	0.388	0.241	0.310	0.336	0.411	0.334
VAR 32	0.323	0.269	0.318	0.338	0.284	0.337
VAR 33	0.306	0.128	0.306	0.228	0.299	0.264
VAR 34	-0.058	-0.021	-0.019	-0.033	-0.160	-0.085
VAR 35	0.262	0.252	0.266	0.202	0.308	0.274
VAR 36	0.401	0.175	0.200	0.310	0.398	0.240
VAR 37	0.068	0.047	-0.022	0.044	0.126	0.227
VAR 38	0.371	0.281	0.331	0.356	0.465	0.389
VAR 39	0.305	0.154	0.250	0.334	0.413	0.315
VAR 40	0.346	0.144	0.291	0.366	0.430	0.418
VAR 41	0.382	0.281	0.262	0.264	0.374	0.411
VAR 42	0.215	0.190	0.154	0.251	0.173	0.306
VAR 43	0.360	0.299	0.256	0.290	0.354	0.280
VAR 44	0.330	0.273	0.237	0.354	0.376	0.259
VAR 45	0.364	0.101	0.217	0.463	0.264	0.230
VAR 46	0.305	0.301	0.165	0.238	0.296	0.301
VAR 47	0.310	0.122	0.272	0.485	0.347	0.260
VAR 48	0.151	-0.068	0.125	0.325	0.141	0.086
VAR 49	0.314	0.206	0.317	0.275	0.365	0.357
VAR 50	0.347	0.220	0.417	0.600	0.346	0.270
VAR 51	0.299	0.184	0.212	0.262	0.225	0.414
VAR 52	0.227	0.185	0.344	0.228	0.159	0.302
VAR 53	0.101	0.064	0.083	0.275	0.124	0.029
VAR 54	0.135	0.246	0.275	0.129	0.077	0.078
VAR 55	0.444	0.140	0.244	0.358	0.397	0.338
VAR 56	0.279	0.220	0.291	0.306	0.336	0.296

	VAR 7	VAR 8	VAR 9	VAR 10	VAR 11	VAR 12
VAR 7	1.000					
VAR 8	0 688	1.000				
VAR 9	0 368	0.348	1.000			
VAR 10	0 274	0 424	0 069	1.000		
VAR 11	0 490	0.545	0 290	0.377	1.000	
VAR 12	0.640	0.517	0.295	0.220	0.475	1.000
VAR 13	0 333	0.296	0.167	0.064	0.213	0.339
VAR 14	0 528	0.571	0.174	0.428	0.426	0.461
VAR 15	0.147	0.213	0.121	0.100	0.155	0.171
VAR 16	0 400	0.420	0.200	0.316	0.403	0.171
VAR 17	0 469	0 410	0.295	0.056	0.451	0.509
VAR 18	0 255	0 274	0.069	0.245	0.208	0.293
VAR 19	0 258	0 246	0.210	0.124	0.390	0.323
VAR 20	0.195	0.172	0.133	0.310	0.267	0.255
VAR 21	0 312	0.296	0.231	0.188	0.339	0.421

	VAR 7	VAR 8	VAR 9	VAR 10	VAR 11	VAR 12
VAR 22	0.296	0 365	0.134	0.101	0.327	0.357
VAR 23	0 288	0 328	0.241	0.129	0.324	0.425
VAR 24	0 090	0 181	0.247	0.079	0 175	0.248
VAR 25	0 250	0.321	0.121	0.129	0.235	0.274
VAR 26	0 176	0 155	0.100	0.148	0.156	0.190
VAR 27	0 233	0 273	0 099	0.157	0.107	0.342
VAR 28	0 063	0 192	0.007	0.098	0.113	0.093
VAR 29	0.214	0 301	0.229	0.002	0.335	0.290
VAR 30	0.418	0 499	0.358	0.173	0.467	0.432
VAR 31	0.365	0.431	0.313	0.175	0.443	0.444
VAR 32	0.276	0 377	0.219	0.144	0 433	0.396
VAR 33	0.281	0.308	0 157	0.130	0.403	0.368
VAR 34	-0.053	0 068	-0 105	0.074	-0 122	-0.137
VAR 35	0 309	0 422	0 146	-0.016	0.343	0.429
VAR 36	0 340	0 363	0 261	0.163	0.295	0.425
VAR 37	0 203	0 284	0.168	0.046	0 165	0.288
VAR 38	0 431	0 487	0 347	0.162	0 361	0.474
VAR 39	0 453	0 444	0 189	0.059	0 376	0.386
VAR 40	0 516	0 478	0 218	0.209	0.366	0.445
VAR 41	0 479	0.507	0 145	0.334	0.274	0.445
VAR 42	0 290	0.395	0 129	0 165	0.247	0.384
VAR 43	0 453	0.492	0.181	0 288	0.370	0.404
VAR 44	0 267	0.314	0 104	0 128	0.326	0 236
VAR 45	0 413	0.362	0 061	0.142	0.388	0 398
VAR 46	0 301	0 150	0.033	0.119	0.176	0.203
VAR 47	0 376	0.347	0.132	0.008	0.441	0.373
VAR 48	0 255	0.190	0.033	0.023	0 318	0.280
VAR 49	0 377	0.403	0.139	0.409	0.259	0.406
VAR 50	0.454	0.488	0.260	0.086	0 464	0.350
VAR 51	0 293	0 278	0 133	0.093	0.309	0.367
VAR 52	0 235	0.337	0.178	0.105	0.334	0.342
VAR 53	0 045	0 093	0.155	-0.129	0.183	0 116
VAR 54	0.104	0 136	0 150	0.101	0.093	0.093
VAR 55	0.381	0 379	0.080	0 163	0.328	0.356
VAR 56	0.339	0 323	0 161	0.161	0.448	0.430

	VAR 13	VAR 14	VAR 15	VAR 16	VAR 17	VAR 18
VAR 13	1 000					
VAR 14	0.269	1.000				
VAR 15	0.098	0.070	1.000			
VAR 16	0 074	0.434	0.018	1.000		
VAR 17	0 261	0.191	0.134	0.136	1.000	
VAR 18	0.043	0.320	0.069	0.123	0.339	1.000
VAR 19	0.216	0.244	0.176	0.175	0.349	0 095
VAR 20	0 198	0.429	0.067	0.013	0.289	0 286
VAR 21	0.207	0.281	-0.100	0.128	0.360	0.277
VAR 22	0.250	0 223	0.163	0.089	0.250	0.221
VAR 23	0 100	0.183	0.039	0.002	0.375	0.119
VAR 24	0 142	0.148	-0.051	0.002	0.219	0 362
VAR 25	0 156	0.259	-0.057	0.153	0.215	0.294
VAR 26	0 154	0 106	0.007	-0.008	0.135	0.208
VAR 27	0.295	0.152	0.120	-0 063	0.218	0.315
VAR 28	0.084	0 035	0.195	-0 125	0.142	0.077
VAR 29	0.213	0.133	0.080	0.001	0.487	0.525
VAR 30	0.254	0.323	0.211	0 339	0.431	0.183
VAR 31	0.203	0 373	0.082	0.197	0.347	0.100
VAR 32	0 309	0.345	0.050	0.248	0.279	0 201
VAR 33	0 188	0 286	0.166	0 223	0.280	0.064
VAR 34	-0 144	0.058	-0.057	0 216	-0.204	0 091

	VAR 13	VAR 14	VAR 15	VAR 16	VAR 17	VAR 18
VAR 35	0.301	0.278	-0.005	0.058	0.388	0.404
VAR 36	0.257	0.288	-0.005	0.215	0.330	0.220
VAR 37	0.246	0.236	0.152	-0.050	0.309	0.261
VAR 38	0.264	0.419	0.070	0.302	0.341	0.206
VAR 39	0.219	0.360	0.054	0.104	0.203	0.095
VAR 40	0.304	0.457	0.155	0.326	0.291	0.294
VAR 41	0.201	0.482	0.028	0.252	0.309	0.214
VAR 42	0.190	0.330	0.217	0.193	0.238	0.139
VAR 43	0.238	0.400	0.087	0.157	0.455	0.337
VAR 44	0.225	0.361	-0.032	0.268	0.135	0.017
VAR 45	0.222	0.345	0.094	0.298	0.312	0.137
VAR 46	0.201	0.271	0.057	0.162	0.182	0.078
VAR 47	0.227	0.227	0.099	0.314	0.373	0.173
VAR 48	0.098	0.186	0.029	0.110	0.227	0.054
VAR 49	0.194	0.309	-0.002	0.278	0.244	0.199
VAR 50	0.241	0.239	0.102	0.289	0.309	0.128
VAR 51	0.261	0.291	0.245	0.254	0.246	0.068
VAR 52	0.091	0.212	0.063	0.247	0.298	0.062
VAR 53	0.056	0.015	0.112	-0.175	0.096	-0.038
VAR 54	-0.068	0.097	0.068	0.194	0.021	0.044
VAR 55	0.173	0.333	0.103	0.091	0.308	0.214
VAR 56	0.327	0.277	0.118	0.152	0.449	0.356

	VAR 19	VAR 20	VAR 21	VAR 22	VAR 23	VAR 24
VAR 19	1.000					
VAR 20	0.322	1.000				
VAR 21	0.249	0.231	1.000			
VAR 22	0.163	0.181	0.451	1.000		
VAR 23	0.340	0.340	0.499	0.460	1.000	
VAR 24	0.062	0.203	0.329	0.222	0.163	1.000
VAR 25	0.207	0.102	0.341	0.112	0.231	0.543
VAR 26	0.043	0.095	0.218	0.206	0.194	0.634
VAR 27	0.278	0.160	0.379	0.166	0.235	0.500
VAR 28	0.068	0.092	0.174	0.095	0.166	0.384
VAR 29	0.204	0.243	0.222	0.244	0.280	0.292
VAR 30	0.254	0.145	0.366	0.497	0.368	0.165
VAR 31	0.355	0.277	0.421	0.565	0.475	0.149
VAR 32	0.335	0.191	0.370	0.442	0.213	0.185
VAR 33	0.302	0.206	0.302	0.525	0.383	0.206
VAR 34	-0.080	0.001	0.032	0.032	-0.008	0.060
VAR 35	0.095	0.166	0.296	0.283	0.276	0.378
VAR 36	0.361	0.230	0.344	0.153	0.269	0.345
VAR 37	0.069	0.312	0.251	0.329	0.217	0.344
VAR 38	0.263	0.253	0.433	0.291	0.276	0.392
VAR 39	0.244	0.191	0.365	0.277	0.259	0.230
VAR 40	0.242	0.253	0.497	0.290	0.340	0.287
VAR 41	0.190	0.265	0.371	0.270	0.398	0.127
VAR 42	0.372	0.159	0.269	0.348	0.322	0.182
VAR 43	0.231	0.237	0.398	0.235	0.369	0.331
VAR 44	0.438	0.173	0.300	0.204	0.358	0.010
VAR 45	0.302	0.033	0.344	0.175	0.152	0.212
VAR 46	0.075	0.047	0.216	0.130	0.072	0.115
VAR 47	0.175	0.037	0.260	0.103	0.170	0.190
VAR 48	0.086	0.079	0.236	0.163	0.184	0.148
VAR 49	0.165	0.206	0.497	0.340	0.305	0.228
VAR 50	0.301	0.095	0.251	0.241	0.165	0.196
VAR 51	0.278	0.101	0.271	0.283	0.295	0.203
VAR 52	0.227	0.129	0.361	0.271	0.328	0.102
VAR 53	0.039	0.154	0.070	0.256	0.078	0.187
VAR 54	0.124	0.062	0.199	0.139	0.056	0.148
VAR 55	0.157	0.283	0.360	0.382	0.336	0.173
VAR 56	0.384	0.383	0.341	0.341	0.401	0.302

	VAR 25	VAR 26	VAR 27	VAR 28	VAR 29	VAR 30
VAR 25	1.000					
VAR 26	0.613	1.000				
VAR 27	0.653	0.528	1.000			
VAR 28	0.339	0.314	0.618	1.000		
VAR 29	0.217	0.178	0.297	0.113	1.000	
VAR 30	0.212	0.113	0.192	0.087	0.295	1.000
VAR 31	0.167	0.107	0.225	0.103	0.238	0.688
VAR 32	0.117	0.058	0.249	0.118	0.276	0.547
VAR 33	0.209	0.148	0.232	0.170	0.188	0.548
VAR 34	0.089	0.020	0.026	-0.028	-0.048	0.006
VAR 35	0.381	0.274	0.333	0.205	0.463	0.250
VAR 36	0.354	0.235	0.416	0.099	0.228	0.230

	VAR 25	VAR 26	VAR 27	VAR 28	VAR 29	VAR 30
VAR 37	0.166	0.164	0.284	0.144	0.226	0.195
VAR 38	0.229	0.207	0.328	0.136	0.238	0.422
VAR 39	0.178	0.210	0.263	0.139	0.212	0.349
VAR 40	0.363	0.295	0.267	0.053	0.251	0.344
VAR 41	0.261	0.138	0.241	0.131	0.235	0.420
VAR 42	0.224	0.095	0.167	0.073	0.155	0.439
VAR 43	0.310	0.283	0.311	0.132	0.246	0.397
VAR 44	0.260	0.094	0.124	0.144	0.110	0.354
VAR 45	0.343	0.191	0.288	0.134	0.108	0.280
VAR 46	0.061	0.058	-0.029	-0.009	0.030	0.241
VAR 47	0.269	0.149	0.144	0.073	0.199	0.273
VAR 48	0.280	0.142	0.158	0.062	0.054	0.120
VAR 49	0.177	0.206	0.199	-0.006	0.084	0.351
VAR 50	0.323	0.184	0.207	0.139	0.146	0.338
VAR 51	0.389	0.198	0.284	0.196	0.138	0.352
VAR 52	0.236	0.171	0.133	0.096	0.066	0.285
VAR 53	0.127	0.157	0.088	0.083	0.191	0.100
VAR 54	0.188	0.097	0.156	0.131	-0.072	0.151
VAR 55	0.203	0.141	0.160	0.056	0.203	0.353
VAR 56	0.331	0.349	0.357	0.159	0.321	0.356

	VAR 31	VAR 32	VAR 33	VAR 34	VAR 35	VAR 36
VAR 31	1.000					
VAR 32	0.813	1.000				
VAR 33	0.751	0.713	1.000			
VAR 34	-0.087	-0.105	0.022	1.000		
VAR 35	0.231	0.339	0.288	-0.154	1.000	
VAR 36	0.295	0.348	0.324	-0.189	0.366	1.000
VAR 37	0.202	0.217	0.228	-0.116	0.420	0.311
VAR 38	0.470	0.383	0.404	-0.081	0.425	0.719
VAR 39	0.377	0.320	0.287	-0.027	0.373	0.379
VAR 40	0.404	0.369	0.429	0.028	0.294	0.445
VAR 41	0.507	0.327	0.435	0.026	0.341	0.277
VAR 42	0.465	0.355	0.382	-0.032	0.192	0.293
VAR 43	0.381	0.448	0.413	0.029	0.403	0.487
VAR 44	0.428	0.283	0.384	0.023	0.120	0.213
VAR 45	0.259	0.243	0.296	0.047	0.207	0.401
VAR 46	0.224	0.147	0.112	-0.016	0.016	0.113
VAR 47	0.284	0.263	0.310	-0.031	0.352	0.433
VAR 48	0.222	0.158	0.224	-0.054	0.210	0.310
VAR 49	0.353	0.262	0.301	0.039	0.186	0.312
VAR 50	0.370	0.328	0.287	-0.042	0.206	0.287
VAR 51	0.351	0.291	0.462	-0.129	0.384	0.366
VAR 52	0.398	0.329	0.401	-0.041	0.337	0.270
VAR 53	0.210	0.166	0.139	-0.083	0.193	-0.004
VAR 54	0.228	0.220	0.172	-0.003	0.110	0.194
VAR 55	0.339	0.267	0.373	-0.049	0.451	0.294
VAR 56	0.366	0.411	0.394	-0.145	0.415	0.456

	VAR 37	VAR 38	VAR 39	VAR 40	VAR 41	VAR 42
VAR 37	1.000					
VAR 38	0.370	1.000				
VAR 39	0.338	0.576	1.000			
VAR 40	0.311	0.565	0.561	1.000		
VAR 41	0.252	0.421	0.500	0.447	1.000	
VAR 42	0.243	0.422	0.499	0.691	0.422	1.000
VAR 43	0.388	0.461	0.459	0.513	0.522	0.438
VAR 44	-0.015	0.238	0.222	0.338	0.376	0.411
VAR 45	0.219	0.461	0.390	0.440	0.279	0.426
VAR 46	0.155	0.200	0.189	0.280	0.248	0.192
VAR 47	0.155	0.483	0.308	0.463	0.266	0.354
VAR 48	0.174	0.307	0.228	0.298	0.218	0.207
VAR 49	0.274	0.425	0.391	0.468	0.496	0.392
VAR 50	0.156	0.423	0.327	0.369	0.242	0.378
VAR 51	0.152	0.408	0.278	0.490	0.337	0.556
VAR 52	0.178	0.423	0.210	0.381	0.246	0.414
VAR 53	0.103	0.067	0.069	0.018	0.014	-0.068
VAR 54	0.115	0.279	0.033	0.138	0.087	0.041
VAR 55	0.338	0.428	0.405	0.497	0.501	0.395
VAR 56	0.435	0.364	0.286	0.430	0.318	0.318

	VAR 43	VAR 44	VAR 45	VAR 46	VAR 47	VAR 48
VAR 43	1.000					
VAR 44	0.339	1.000				
VAR 45	0.323	0.320	1.000			
VAR 46	0.284	0.123	0.170	1.000		

	VAR 43	VAR 44	VAR 45	VAR 46	VAR 47	VAR 48
VAR 47	0.265	0.250	0.728	0.030	1.000	
VAR 48	0.150	0.165	0.606	-0.017	0.750	1.000
VAR 49	0.437	0.294	0.244	0.338	0.187	0.104
VAR 50	0.216	0.306	0.553	0.243	0.557	0.535
VAR 51	0.262	0.461	0.398	0.061	0.456	0.370
VAR 52	0.299	0.270	0.367	0.131	0.365	0.267
VAR 53	0.015	0.104	0.033	-0.030	0.042	0.041
VAR 54	0.169	0.031	0.211	0.056	0.138	0.118
VAR 55	0.531	0.394	0.288	0.263	0.332	0.233
VAR 56	0.461	0.323	0.284	0.195	0.321	0.215

	VAR 49	VAR 50	VAR 51	VAR 52	VAR 53	VAR 54
VAR 49	1.000					
VAR 50	0.224	1.000				
VAR 51	0.230	0.424	1.000			
VAR 52	0.293	0.327	0.545	1.000		
VAR 53	-0.071	0.066	0.051	0.112	1.000	

	VAR 49	VAR 50	VAR 51	VAR 52	VAR 53	VAR 54
VAR 54	0.099	0.067	0.230	0.352	0.390	1.000
VAR 55	0.474	0.410	0.394	0.345	0.087	-0.004
VAR 56	0.312	0.313	0.374	0.270	0.115	0.264

	VAR 55	VAR 56
VAR 55	1.000	
VAR 56	0.439	1.000