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INVESTIGATING THE LINKAGE BETWEEN TOTAL QUALITY MANAGEMENT AND ENVIRONMENTALLY RESPONSIBLE MANUFACTURING

By

Sime Curkovic

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ABSTRACT

INVESTIGATING THE LINKAGE BETWEEN TOTAL QUALITY MANAGEMENT AND ENVIRONMENTALLY RESPONSIBLE MANUFACTURING

By

Sime Curkovic

The overarching goal of this dissertation was to investigate the theoretical linkage between Total Quality Management (TQM) and Environmentally Responsible Manufacturing (ERM) by answering the following research questions: 1) Is there a relationship between TQM and ERM based systems; and, 2) If there is a relationship between TQM and ERM, then what is the nature of the relationship? An additional contribution was to help build ERM theory by answering the following ancillary research question: 3) Are the TQM constructs good predictors for the ERM constructs?

The dissertation was undertaken using a two-phase approach: 1) preliminary scale development was conducted using interviews with industry managers; and, 2) implementation of a large scale survey. More specifically, the sample was targeted towards plant managers across a 4-digit SIC code within the U.S. automotive industry: Motor Vehicle Parts & Accessories (SIC 3714). A total of 526 usable questionnaires were returned, yielding an effective response rate of 17.86% (N = 2,945 plants). The nature of the concerns represented by the research questions required that a structural equation modeling approach be used.

The empirical results of this dissertation support the TQM-to-ERM link which previously represented an unexplored proposition. The results suggest that firms with advanced TQM systems in place also have more advanced ERM systems than firms just initiating TQM. In other

words, ERM based systems will be stronger in firms as TQM based systems become more developed. What is being argued with these results is that TQM systems condition firms to be more interested in the need for an ERM system. When a TQM system precedes ERM, it increases the probability of an ERM system being present.

Because the two concepts of TQM and ERM share a similar focus, it makes sense to use many of the tools, methods, and practices of TQM in implementing an ERM based system. Given this perspective, the structure of ERM systems was expected to parallel or be very similar to that found in TQM systems. The results suggest that TQM can serve as a ready bridge for an ERM based system. In other words, TQM affects the resulting structure of the ERM based system.

The TQM measurement model was operationalized using a set of four multi-item scales corresponding to the four factors associated with the Malcolm Baldrige National Quality Award (MBNQA) framework (e.g., TQM Strategic Systems, TQM Operational Systems, TQM Information Systems, and TQM Results). Likewise, ERM was operationalized in terms of the four factors described by the MBNQA framework (e.g., ERM Strategic Systems, ERM Operational Systems, ERM Information Systems, and ERM Results). The MBNQA framework was adapted to address environmental issues and furthermore, it was shown that the framework can be used a basis for an integrative definition of ERM. The four-factor structures of the initially hypothesized TQM and ERM confirmatory factor analysis measurement models were retained in the final models. In other words, the TQM constructs were good predictors for the ERM constructs. This adaptation of the MBNQA framework suggests that quality principles can

be seamlessly integrated into the practice of managing environmental issues.

This dissertation has developed an integrated theory about how TQM based capabilities can be leveraged for ERM. It suggests that efforts should be coordinated to take advantage of the potential synergies between TQM and ERM. The means for capturing these synergies can be accomplished by using the MBNQA framework.

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CHAPTER 1

OVERVIEW OF THE RESEARCH

1.1 Introduction

Environmentally Responsible Manufacturing (ERM) is a relatively new concept which can be viewed as a product of the 1990s. ERM has been defined as an economically-driven, system-wide and integrated approach to the reduction and elimination of all waste streams associated with the design, manufacture, use and/or disposal of products and materials (Melnyk and Handfield 1995). Fundamental to ERM is the recognition that pollution, irrespective of its type and form, is waste. As we are aware from past experiences with the concepts of Just In Time (JIT), Total Quality Management (TQM), and Time Based Competition (TBC), waste is any activity or product which consumes resources or creates costs without generating any form of offsetting stream of value (Porter 1991; Porter and Van der Linde 1995a, 1995b). By minimizing waste, the firm can reduce disposal costs and permit requirements, avoid environmental fines, boost profits, discover new business opportunities, rejuvenate employee moral, and protect and improve the state of the environment. From an operations management perspective, simultaneous cost reduction and waste reduction are being demonstrated throughout processes in areas encompassing shipping and distribution costs, raw material costs, actual manufacturing and processing costs, packaging costs, costs of treatment or disposal of process emissions, landfill use costs, and customer disposal costs (Hanna and Newman 1995).

When viewed in this light, it would be expected that more managers be interested in the implementation and use of ERM based systems. After all, ERM involves the identification and elimination of in-process waste

streams. However, for most firms, ERM has not achieved the same degree of acceptance as have JIT, TQM, and TBC (Makower 1993, 1994; Epstein 1996). In practice, most firms are unable to justify the assumption of a leadership role when it comes to ERM. Leadership responses would include focusing on the firm's processes to see whether they might be made environmentally safer, rather than just on problems as they occur; or considering societal needs that go beyond existing legislation and regulation. If successful, this approach can help put the firm in position where it can help to dictate regulations and standards rather than be influenced by them.

However, for most companies, compliance is seen as an adequate position to assume (Bavaria 1996; Epstein 1996). With compliance, the firm does only what is necessary to meet the letter of the law. It is a reactive position which means environmental problems are corrected once they have been created. This is relatively ineffective because it does not attack the causal factors, merely the symptoms (Carpenter 1991). It is also a potentially dangerous position given the retroactive and dynamic nature of many laws. That is, what may be in compliance today may be considered to be out-of-compliance tomorrow. As a result, the firm may find itself always spending to bring itself into compliance with regulations that are continuously becoming more stringent.

The challenge of determining whether it is better for the firm to simply emphasize compliance or whether the firm wants to become recognized as an industrial leader in the development and application of ERM based systems describes the first of many obstacles and paradoxes surrounding ERM. In large part, the failure of management to become more environmentally responsible is really a reflection of its inability

to address and resolve these paradoxes and problems. The following are some of the most important paradoxes and problems associated with the development and implementation of ERM systems:

- Top management must be willing to accept and champion corporate-wide developments if ERM is to become widespread (Hunt and Auster 1990; Schot 1991; Epstein 1996). However, when dealing with ERM, there is a strong bias in favor of ignorance at the highest levels of the firm (Melnyk 1995).

- In the short run, implementing ERM often causes costs to rise (Palmer, Oates, and Portney 1995). However, there is a real concern as to whether customers are willing to pay the added costs associated with having something that is environmentally friendly (Rosewicz 1990).

- It has been argued that being environmentally responsible ultimately makes a company more efficient and more competitive (Royston 1980; Bonifant 1994a, 1994b; Bonifant and Ratcliff 1994; Van der Linde 1995a, 1995b, 1995c). However, there are many reported cases of ERM investments which have resulted in negative returns (Jaffe, Peterson, Portney, and Stavins 1993, 1994; Walley and Whitehead 1994).

- Ideally, the most appropriate place for considering ERM issues is in the design phase since the amount of waste generated is a direct consequence of decisions made during design (Bowman 1996; Fiskel 1993, 1996). However, there is a lack of appropriate measures and tools for capturing the environmental impact of designs (Van Weenen and Eeckles 1989; Allenby 1993; Graedel and Allenby 1995).

- Managers need frameworks or guidelines which they can use to better understand what ERM is and its components. However, a great deal of the information surrounding ERM is either legally based or derived from anecdotal stories and case studies (Piet 1994; Danesi 1996).

- Managers have difficulty assessing the impact of ERM measures and programs because of the lack of appropriate measures. In order for ERM to be given serious consideration by a firm, a process is required for evaluating ERM by appropriately including environmental costs and savings for each investment option (Sarkis and Rasheed 1995; Epstein 1996).

It is these paradoxes and problems which have encouraged research into ERM. At present, three streams of research can be identified from the literature pertaining to ERM. The first stream focuses on investigating the relationship between ERM and business performance.

The relationship between ERM and business performance has been the subject of great debate in the literature. The environmental movement, and much of today's environmental regulation, has traditionally been viewed as a costly deterrent to productivity (Carpenter 1991; Jaffe, Peterson, Portney, and Stavins 1993, 1994; Oates, Palmer, and Portney 1993; Walley and Whitehead 1994; Hanna and Newman 1995). However, some researchers have recently argued that firms can contribute to waste reduction and ultimately profit improvements by focusing on ERM (Porter 1991; Bonifant 1994a, 1994b; Porter and Van der Linde 1995a, 1995b). Since then, there has been a growth of interest from both managers and researchers to reconcile economic growth with the conservation of natural resources (Long 1995; Wollard 1996).

To further fuel the debate, results of empirical research have been mixed, with ambiguous or conflicting conclusions (Aupperle, Carroll, and Hatfield 1985; Ulmann 1985; Capon, Farley, and Hoenig 1990; Klassen 1995). One of the research challenges ahead for ERM is to develop the link between business' economic self-interests and protection of the environment. Unlike TQM, JIT, and TBC, where there is a proven link between improved performance on these dimensions and enhanced corporate performance, the nature of the linkage between ERM and corporate performance has yet to be conclusively established. Within this stream of research, establishing metrics of performance (both for ERM and the firm) and the establishment of the determination and size of causality remain open issues.

The second stream of research pertaining to ERM deals with identifying what constitutes an effective and efficient ERM system. Even though some managers embrace the concept of ERM without

understanding its short- and long-term impact or the extent of commitment required at all levels, the key elements which lead to successful ERM systems in organizations are not well understood (Klassen 1995; Epstein 1996). Managers need a methodology for discovering solutions that yield the greatest benefits and they need specific guidance on implementation issues which are generalizable between firms (Piet 1994; Danesi 1996). While many firms have adopted some form of ERM, their implementation has not been equally successful (Walley and Whitehead 1994).

The reasons for implementation failure are not well understood. However, unfocused efforts may lead to failed ERM based systems. Although this second stream of research does not examine linkages among the various constructs and their impact on performance, several elements of ERM systems have emerged from reported conceptual papers, case studies, and empirical research. For example, management leadership, written policy, and long-term planning are among the most commonly implemented elements of ERM systems. But due to a paucity of insights into the interactions among these various elements, organizations employ them in isolation. In other words, ERM is being implemented in piecemeal fashions. A majority of the writings within this stream of research has provided managers with normative prescriptions and managerial guidelines, but it has failed to address how to develop and successfully implement ERM.

The third and final stream of research pertaining to ERM looks at whether there are any precedents to the emergence of ERM. That is, this stream is interested in determining if there are any systems that by their presence encourages the emergence and acceptance of ERM. For the

most part, this stream of research has focused on the relationship between TQM and ERM. Although originally applied to operations management for the purpose of improving product quality (i.e., reducing product waste in time, materials, and labor), the concept of TQM is being translated to the realm of ERM. It has been suggested by several researchers, through mostly conceptual analyses and case studies, that significant benefits arise from applying what has been learned about TQM to environmental issues (Habicht 1991; Alm 1992; Friedman 1992; Post and Altman 1992; Wheeler 1992; Klassen and McLaughlin 1993; Makower 1993; Neidart 1993; Thompson and Rauck 1993; Woods 1993; Willig 1994; Hanna and Newman 1995; May and Flannery 1995; Sarkis and Rasheed 1995; Epstein 1996; Rondinelli and Berry 1997).

Some researchers, such as Makower (1993) and Willig (1994), bring together first-hand reports on how leading companies are going beyond meeting regulatory compliance to gaining competitive advantage and improved profitability by applying TQM practices to ERM. In these studies, the authors describe how the implementation of ERM can be made more successful by integrating it into a TQM system. TQM processes for elimination of wastes were shown to significantly improve environmental performance while simultaneously creating improvements in productivity.

What is being argued within this stream of research is that TQM systems condition firms to be more interested in the need for an ERM system. When a TQM system precedes ERM, it is postulated to have two major affects. First, it increases the probability of an ERM system being present. The systematic view of TQM, encompassing both the finished product or service and all the supporting activities to provide them, provides a strong rational for an explicit focus on ERM. Second,

it affects the resulting structure of the ERM system. In other words, TQM serves as a ready bridge to ERM.

Proctor & Gamble, 3M, and AT&T are excellent examples of companies which were among the first to extend their TQM initiatives to ERM (Shedroff and Bitters 1991; Thompson and Rauck 1993; Sandelands 1994). These companies utilized TQM approaches to work towards a goal of zero waste discharges. Relevant TQM principles which were integrated into their waste minimization programs include: 1) a systems analysis process orientation that aimed to reduce inefficiencies and identify product problems; 2) data-driven tools, such as cause and effect diagrams, quality evolution charts, pareto analysis, and control charts, to signal problems with the manufacturing process; and 3) a team orientation that uses the knowledge of employees to develop solutions for waste problems. Each company now reports aggregate savings and significant environmental benefits generated by using the TQM concepts in environmental management.

This dissertation deals primarily with the last stream of research discussed. Specifically, the research presented in this dissertation investigates whether the presence of a relationship between TQM and ERM systems exists, and if so, the structure parallels between these two systems. It should be noted that there are several issues that this dissertation will not investigate. It will not investigate the relationship between ERM systems and corporate performance. It will also not directly investigate what constitutes an effective and efficient ERM system. However, this research is important because it will clarify much of the confusion surrounding the assumed relationship between TQM and ERM.

1.2 Primary Research Questions

There has been a great deal of discussion within the literature about TQM in environmental programs. ERM appears to be an area with strong potential for the development of process improvements; however, it has largely been ignored by operations practitioners and academics to date. Furthermore, many organizations, some of which tout the TQM philosophy, fail miserably as indicated by noncompliance (Augenstein 1995). The normative literature and case studies which predominates the ERM field suggests, but does not explicitly recognize, that in TQM there is an explainable, understandable, and documental path to ERM. Such postulated associations between TQM and ERM are mostly based on deductive reasoning and case analysis. Unfortunately, while case studies and deductive arguments have emphasized the virtues of TQM's role in ERM, researchers have not supported these arguments with extensive systematic empirical analyses. The overarching goal of this dissertation is to investigate the theoretical linkage between TQM and ERM via a structural equation model by answering the following research questions:

1. Is there a relationship between TQM and ERM systems?

2. If there is a relationship present between TQM and ERM, then what is the nature of the relationship?

These questions collectively reflect an interesting premise. Namely, ERM systems are viewed as being TQM systems modified to do deal with environmental issues. The gradual evolution of quality to include aspects of the environment has been anticipated by several authors (Mizuno 1988; May and Flannery 1995; Sarkis and Rasheed 1995; Epstein 1996). The "no waste" aim of ERM based systems closely parallels the

TQM goal of "zero defects." TQM focuses on waste as it applies to process inefficiencies, whereas ERM tends to focus more on concrete outputs, such as solid and hazardous waste. Because the two concepts share a similar focus, it makes sense to use many of the tools, methods, and practices of TQM in implementing an ERM based system. Given this perspective, the structure of ERM systems is expected to parallel or be very similar to that found in TQM systems. In addition, a linkage between overall TQM and ERM systems is expected. Given this premise, the dissertation is interested in determining the presence of a relationship between TQM and ERM systems. In addition, this dissertation is interested in exploring the similarities and differences between the structures of these systems.

1.2.1 Ancillary Research Question

The relationship between TQM and ERM is being examined while ERM theory is far from being fully developed (Post and Altman 1992; Klassen 1995). As will be presented in Chapter 2, the ERM literature suffers from a lack of: 1) systematic scale development; 2) content validity; and 3) empirical validation. In Section 2.8, parallels are drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM can be adapted for ERM. Therefore, an adaptation of the operational framework for TQM is used as the framework for ERM. For example, ERM is operationalized using four multi-item scales corresponding to an adaptation of the four categories associated with the operational framework for TQM (see Section 1.2.2). The expected scholarly contribution of this dissertation, in addition to investigating the theoretical linkage between TQM and ERM and the nature

of this relationship, is to help build ERM theory by answering the following ancillary research question:

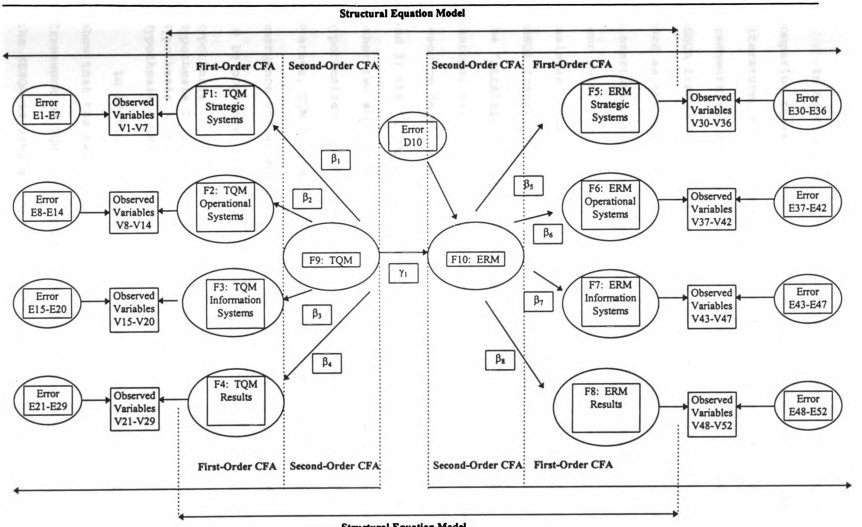
3. Are the TQM constructs good predictors for the ERM constructs?

ERM theory building will require a more forward and comprehensive outlook in which the theoretical constructs of ERM are developed. Furthermore, the advancement of the ERM field depends on giving priority to measurement. This is because theory construction and cumulative tradition, the ultimate objectives of any field, are inseparable from measurement (Bagozzi 1980). Thus, in order to move from anecdotes and case studies to testable models and hypotheses, it is critical to link theoretical concepts such as ERM to empirical indicants. In search for substantive relationships, the ERM field has overlooked the methodological issues such as measurement. This dissertation will contribute to ERM theory building by identifying the constructs associated with ERM, developing scales for measuring these constructs, and empirically validating the scales.

1.2.2 Specific Research Hypotheses

The structural equation model to be tested is shown in Figure 1.1. All paths are expected to have positive signs. The justification for these paths (i.e., βs and γ) is given below with more comprehensive explanations provided in Chapter 3 (Section 3.2). Note, that all of the hypotheses relate to association, and not causation.

Figure 1.1. Dissertation Research Model



- Each first-order factor and F10 has a disturbance term associated with it (e.g., D1, D2, D3, D4, D5, D6, D7, D8, D10).
- See Appendix A for each observed variable as it appeared on the measurement instrument.

In Section 2.4, using the traits associated with TQM, and comparing these traits to the various constructs found in the literature, the Malcolm Baldrige National Quality Award (MBNQA) framework was determined to best fit the definition of TQM. Since the MBNQA framework is most consistent with the definition of TQM, it is used as the operational framework of TQM for the purposes of this dissertation research. For example, TQM will be operationalized using four multi-item scales which correspond to the three subsystems and the business results category associated with the MBNQA framework. The 1997 MBNQA framework is viewed as three related subsystems (Evans 1997): 1) the "strategic" categories of leadership, strategic planning, and customer/market focus; 2) the "operational" categories of human resource development and process management (which lead to "results"); and 3) the "information" category which serves as the foundation for the other two subsystems. In light of the above discussion, it is hypothesized that the presence of TQM Strategic Systems, TQM Operational Systems, TQM Information Systems, and TQM Results encourages the emergence and acceptance of TQM; thus, β_1, β_2, β_3, and β_4 are proposed to be positive. More specifically:

Hypothesis 1 (H1): $\beta_1 > 0$, $p < 0.05$
Hypothesis 2 (H2): $\beta_2 > 0$, $p < 0.05$
Hypothesis 3 (H3): $\beta_3 > 0$, $p < 0.05$
Hypothesis 4 (H4): $\beta_4 > 0$, $p < 0.05$

In Section 2.8, parallels are also drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM can be adapted for ERM; therefore, an adaptation of the MBNQA is used as the operational framework of ERM. For example, ERM is operationalized using four multi-item scales corresponding to an

adaptation of the four categories associated with the MBNQA framework. Thus, it is proposed that the presence of ERM Strategic Systems, ERM Operational Systems, ERM Information Systems, and ERM Results encourages the emergence and acceptance of ERM, as is shown by β_5, β_6, β_7, and β_8 in Figure 1.1. More specifically:

Hypothesis 5 (H5): $\beta_5 > 0$, $p < 0.05$
Hypothesis 6 (H6): $\beta_6 > 0$, $p < 0.05$
Hypothesis 7 (H7): $\beta_7 > 0$, $p < 0.05$
Hypothesis 8 (H8): $\beta_8 > 0$, $p < 0.05$

Several researchers suggest that organizations with TQM systems in place are more inclined to undertake ERM systems than companies with less commitment to TQM. It has been suggested that that a company's ability to reframe learnings from TQM was crucial to ERM. Limited evidence has been presented that TQM systems are being used as models for ERM systems. The demonstrated similarity between TQM and ERM suggests the need for an empirical investigation which examines whether firms which have advanced TQM systems in place also have more advanced ERM systems than firms just initiating TQM. Although these findings have been suspected, no research has provided empirical support for what are mostly deductive arguments. Thus, it is hypothesized that the presence of a TQM based system encourages the emergence and acceptance of an ERM based system. More specifically:

Hypothesis 9 (H9): $\gamma_1 > 0$, $p < 0.05$

One of the primary objectives of this dissertation is to compare how the structures of TQM based systems parallel those of ERM based systems. There is no reason, a priori, to believe that the structures associated with TQM and ERM based systems are different; therefore, the

structures between TQM and ERM based systems are hypothesized to be similar or parallel one another. More specifically:

Hypothesis 10 (H10): $\beta_1 - \beta_5 = 0,\ p < 0.05$
Hypothesis 11 (H11): $\beta_2 - \beta_6 = 0,\ p < 0.05$
Hypothesis 12 (H12): $\beta_3 - \beta_7 = 0,\ p < 0.05$
Hypothesis 13 (H13): $\beta_4 - \beta_8 = 0,\ p < 0.05$

1.3 Research Methodology

The nature of the concerns represented by the research questions and specific research hypotheses requires that a structural equation modeling approach be used. The reasons for the attractiveness of structural equation modeling are three fold: 1) it provides a straightforward method of dealing with multiple relationships simultaneously while providing statistical efficiency; 2) its ability to assess the relationships comprehensively has provided a transition from exploratory to confirmatory factor analysis; and 3) its ability to represent unobserved concepts in these relationships and account for measurement error in the estimation process. This dissertation effort requires the ability to test a series of relationships constituting a large-scale model, a set of fundamental principles, and even an entire theory. These are a task for which structural equation modeling is well suited.

Investigating the theoretical linkage between TQM and ERM systems, as well as allowing for a deeper investigation of the underlying constructs, will be undertaken using a two-phase approach: 1) preliminary scale development will be conducted using interviews with industry managers; and 2) implementation of a large scale survey designed to validate scales for measuring the underlying constructs associated with TQM and ERM systems, and their relationships. This

combination will allow for the exploitation of the strengths of both case studies and surveys while reducing the problems associated with both.

The primary objective of the first phase was to provide an indication of content validity. Interviews with managers in six North American manufacturing facilities were used to provide assistance in the identification and prima facie validation of the constructs and variables in the dissertation. Each manager completed the questionnaire and provided feedback regarding the wording of items, their understandability, and the overall organization of the measurement instrument. The instrument was adjusted accordingly based on their feedback.

Similar to much of the research in operations strategy, a single industry was chosen for the dissertation. This restriction permits the control of several variables that often differ between industries, including the scope and complexity of quality and environmental concerns. To empirically test a model dealing with TQM and ERM, an ideal industry would have three primary characteristics (Klassen 1995; Ahire, Golhar, and Waller 1996): 1) a high degree of variation in ERM based systems; 2) a leader in the implementation of progressive quality management strategies; and 3) a competitive marketplace. Based on these criteria, the automotive industry was chosen (see Section 3.5.2).

More specifically, the sample will be targeted across a 4-digit SIC code within the U.S. automotive industry: Motor Vehicle Parts & Accessories (SIC 3714). A mailing list of plant managers at 2,945 manufacturing facilities across this SIC code has been obtained. The focus of the survey will be on the real TQM and ERM related decisions

made by plant managers and the ultimate effect of these decisions, as viewed by them. Consequently, all data will be based on managers' perceptions.

1.4 Scope of the Dissertation

The structural equation model in Figure 1.1 is not all inclusive. All relevant factors have not been identified and all the linkages among them have not been fully developed. This dissertation primarily deals with investigating the presence of the relationship between TQM and ERM based systems and the structure parallels between these two systems. It should be noted in greater detail than was previously discussed that there are several issues that this dissertation will not investigate. First, it will not investigate the relationship between ERM systems and corporate performance. Second, it will not directly investigate what constitutes an effective and efficient ERM system. Clearly, the effectiveness and efficiency of an ERM based system will be dependent on several factors independent of TQM, including: industry type, type of regulations companies must comply with, company size, overseas experience, and the external orientation of a company.

It would be beyond the scope of this dissertation to address all these factors. A complete model of all the factors which potentially influence ERM would encompass many variables and be difficult if not impossible to test statistically for a couple of reasons. The first problem is one of sample size. The large sample size required to test such a model would be expensive and time-consuming. In addition, the model would be difficult to explain in a rational manner.

1.5 Contribution of the Research

Despite the issues which this dissertation will not investigate, this research is important for several reasons. First, research directed at developing a rationally consistent theory of ERM which can be consistently related to management theories such as TQM represents an interesting and unexplored proposition. Expanding TQM to the management of the environment appears to have significant benefits. Just as the concept of TQM forced a change in the economic paradigms of quality, companies pursuing ERM practices have been able to overcome the traditional economic assumption that ERM reduces productivity (Hanna and Newman 1995). Should such a theory be organized into a substantiated, broadly applicable approach, it could form the basis of a transformation of how environmental issues are addressed by operations management, similar to that which came out of the TQM movement.

Second, the implications of the results should be of considerable value and interest to managers faced with the complex task of addressing the need to become more environmentally responsible. Managers in nearly every industry are being asked to examine their products and manufacturing processes with an eye towards the reduction and elimination (if possible) of any polluting waste streams. The findings of this research should provide important managerial guidelines concerning appropriate managerial actions to take in the development of ERM based systems. Currently, the ERM field falls short on overall generalizability of results, and managers, of course, are more interested in broad, general managerial approaches (Cairncross 1992; Klassen 1995).

Third, while much of the TQM and ERM literature uses univariate or bivariate techniques, this dissertation advances methodology by performing structural equation modeling. Use of a structural equation model is designed to test whether the theoretical model, which was developed based on case studies and theory, can be rejected. The modeling approach used to investigate the theoretical linkage between TQM and ERM is more quantitatively sophisticated than techniques typically used in the literature. Typically, research emphasis in general has progressed from theory building to theory testing, from qualitative to quantitative methods. While the ERM literature evolved somewhat in this manner, there is still too much reliance on descriptive research (Hanna and Newman 1995; Klassen 1995). Although less quantitative methods continue to offer richness, structural equation modeling approaches offer increased internal validity.

The structural equation model in Figure 1.1 will be tested using EQS for Windows (Version 5.5) with covariance matrices as input. Two second-order latent variable measurement models will be used to refine and validate the constructs associated with TQM and ERM. This dissertation research differs significantly from other empirical work in terms of the overall approach used for scale development and validation. As will be evident from Chapter 3, this dissertation research draws upon more current and comprehensive scale validation techniques used in the marketing and social sciences literature to yield more reliable and valid scales. For example, confirmatory factor analysis (CFA) is used to refine and validate the scales associated with the TQM and ERM constructs. The measurement models for TQM and ERM will be tested using CFA before assessing the structural relationships shown in Figure 1.1.

CFA will be performed for each measurement model since CFA is a more rigorous method for assessing unidimensionality than coefficient alpha, exploratory factor analysis, and item-total correlations (Gerbing and Anderson 1988). The purpose is to ensure unidimensionality of the multiple-item constructs and to eliminate unreliable items from them. After eliminating items that load on multiple constructs or have low item-to-construct loadings, the Bentler-Bonett normed fit index (NFI), nonnormed fit index (NNFI), and comparative fit index (CFI) for both measurement models will be used to assess the fit of the CFA models to the data (Calantone, Schmidt, and Song 1996). Once the measurement issues for each measurement model are satisfactorily resolved, the structural equation model in Figure 1.1 will be tested.

Under a structural equation modeling approach, a variety of unobservable variables can cause model specification errors (Hughes, Price, and Marrs 1986; Bollen 1989; Calantone, Schmidt, and Song 1996); therefore, there is concern for possible biases influencing the results. In other words, omitted variables may significantly bias the results and interpretations (Boulding and Staelin 1990, 1995). Thus, there is a hidden threat to the validity of the results in this context. Tests which will be conducted to insure that specification errors are not biasing the results include: 1) a test of the theta delta matrix for each CFA model; and 2) an examination of nomological validity (Bagozzi and Yi 1989; Bollen 1989).

The use of the structural equation model in Figure 1.1 was designed to test whether the theoretical model can be rejected. While the directionality of the relationships was established theoretically, it is possible to argue that the directionality of the hypotheses could

be reversed in some instances. For example, a causal relationship could be posed depicting TQM from ERM; however, there is no support in the literature for this relationship. The results would be grossly misleading because there is a conceptual flaw in the reversed relationship. The TQM-to-ERM link forms the proposed relationship for the theoretical model. Ideally, one needs to collect time-series data to test causal relationships. While this dissertation will test if the model is consistent with the data, it will not be able to establish absolute causality.

1.6 Structure of the Dissertation

The dissertation is organized as follows. Chapter 2 offers a comprehensive review of the relevant literature accumulated from the early 1970s through 1997. The literature which supports this dissertation topic includes research conducted within two main bodies of literature. The first body of literature pertains to TQM; and the second pertains to ERM. Chapter 3 covers pre-research and research design issues, while Chapter 4 presents an analysis of the data. A discussion of the results and corresponding conclusions are supplied in Chapter 5. An extensive list of references is also provided along with a copy of the primary survey instrument in the attached Bibliography and Appendix.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

The literature which supports this dissertation topic includes research conducted within two main bodies of literature. The first body of literature discussed pertains to Total Quality Management (TQM); and the second pertains to Environmentally Responsible Manufacturing (ERM). The TQM section precedes the ERM section, and begins with a definition of the concept and discusses its importance. Then, three different categories of frameworks from the literature are used to identify the constructs associated with TQM and the items that represent manifestations of these constructs. The frameworks are based on the source of the criteria. Three different categories of frameworks emerge from the literature: 1) anecdotal; 2) empirically-based research; and 3) formal assessment processes. These frameworks are used to examine the various attempts to operationalize TQM with the goal of identifying the similarities and differences. Next, going back to the definition of TQM, a series of traits associated with TQM are identified. Using these traits, the various constructs found in the three categories of frameworks are reviewed to determine which framework best fits the definition of TQM. These results are then used to identify an operational framework of TQM. The TQM section concludes by establishing the concept as a foundational requirement for other developments such as Time Based Competition (TBC)and Just In Time (JIT). The argument that TQM must precede major developments will set the stage for arguing that TQM precedes ERM, which is the next main body of literature discussed.

The ERM section is very similar in structure to the TQM section. It begins with a definition of the concept, an identification of its primary traits, and a discussion of its importance. Then, three categories of frameworks are used to identify the various constructs associated with ERM and the items that represent manifestations of these constructs. The frameworks are also based on the source of the criteria and includes: 1) anecdotal; 2) empirically-based research; and 3) formal assessment processes. Then, the potential links between the concept and methodology of TQM and ERM are reviewed. Parallels are drawn to show that an operational framework of TQM can be adapted for ERM. This chapter concludes by identifying an operational framework of ERM. With operational frameworks for both TQM and ERM, the relationship between TQM and ERM can be investigated.

2.2 Total Quality Management

Recent developments in global markets have highlighted the increasing importance of quality management. U.S. firms have been challenged to produce better quality products by competitors from overseas countries such as Germany and Japan (Lawrence 1980; Schonberger 1982). Many experts contend that a decline in product quality has significantly eroded the competitiveness of American firms (Jackson and O'Dell 1988). In other words, quality products and services are essential for firms seeking to compete globally. Companies that improve quality acquire a competitive advantage through quality-induced product differentiation; the creation of a good or service that is perceived as unique (Shetty 1993). Once recognized as an order-winner, high product quality is now widely recognized as an order-qualifier (Handfield and Ghosh 1994). Although there are many different

ways to differentiate products, superior quality is one of the most effective, one which results in a defensible competitive position and insulates a firm against inroads of rival firms (Porter 1980).

U.S. firms responded to global competition by focusing on shop floor programs (e.g., quality control circles) in an attempt to emulate the German and Japanese productivity achievements (Wheelwright 1981; Limprecht and Hayes 1982). However, a closer look at the evolution of world class manufacturing excellence achieved by Germany and Japan revealed that a more integrated approach to quality management was being used (Garvin 1984 and 1986; Lee and Ebrahimpour 1985). As a result, quality management shifted from being a statistical view of process control towards being a broad-based definition considering the entire value-chain, with a strong internal and external customer orientation (Enrick 1985; Juran and Gryna 1988; Tank 1991).

Based on the pioneering work of Deming, the term "Total Quality Management" (TQM) emerged over a decade ago in the U.S. and embodied a broad scope of activities within the framework of world class manufacturing (Deming 1981, 1982, and 1986). TQM itself is an integrated management philosophy and set of practices that establishes an organization-wide focus on quality, merging the development of a quality-oriented corporate culture with intensive use of management and statistical tools aimed at designing and delivering quality products to customers (Melnyk and Denzler 1996). TQM stresses three major principles: customer satisfaction, employee involvement, and continuous improvements in quality. This definition goes on to state that TQM also involves: benchmarking, product and service design, process design, long-range thinking, and problem-solving tools.

Logothetis (1992) describes TQM as "a culture; and inherent in this culture is a total commitment to quality and attitude expressed by everybody's involvement in the process of continuous improvement of products and services, through the use of innovative scientific methods." Perhaps one of the most salient definitions of TQM was provided by the *Report of the Total Quality Leadership Steering Committee and Working Councils* (Evans 1992). This council consists of a number of CEOs from major corporations, as well as a number of academic representatives from distinguished schools across the country. Through intensive literature reviews and discussion, this council developed the following definition of TQM:

> a people-focused management system that aims at the continual increase of customer satisfaction at continually lower real cost. Total Quality is a total system approach (not a separate area or program), and an integral part of high-level strategy; it works horizontally across functions and departments, involves all employees, top to bottom, and extends backwards and forwards to include the supply chain and customer chain (Evans 1992).

Many U.S. multinational organizations are adopting TQM principles in an urgent and rigorous manner, in an attempt to recover their equilibrium in the global marketplace. An *Industry Week* article (Benson 1993) claimed that during the last 10 years, TQM has become as pervasive a part of business thinking as quarterly financial results. A 1992 Arthur D. Little study also reported that 93% of America's largest 500 firms have adopted TQM in some form. These companies are engaged in a variety of "best practice" TQM programs, in the hope of improving business performance by offering higher quality products and services. Aggressive practitioners of TQM such as Xerox, Hewlett-Packard, and Motorola have targeted an ambitious new goal of offering perfect products to customers, with no defects at all in design, manufacturing,

or delivery (Melnyk and Denzler 1996). Several studies now posit that unless corporations adopt the principles of TQM, they will be unable to compete with global competitors, leading to major shifts in firm and industry market structures (Womack, Jones, and Roos 1990; Bowles and Hammond 1991; Shetty 1993; Handfield 1993; Powell 1995).

2.3 Categories of Frameworks

Three different categories of frameworks emerge from the literature: 1) anecdotal; 2) empirically-based research; and 3) formal assessment processes. The anecdotal category is based on the personal experiences of quality gurus such as Deming, Juran, and Crosby. The empirically-based research category looks at formal research studies with increased attention given to studies whose thrust was the development and validation of TQM measurement instruments. The third and final category examines popular formal international and national assessment processes such as ISO 9000 and the Malcolm Baldrige National Quality Award. These three categories of frameworks are used to identify the various views of the constructs associated with TQM and the items which represent manifestations of these constructs.

2.3.1 Anecdotal

Several individuals have strongly influenced companies in both manufacturing and service sectors to emphasize quality. Initially, their ideas found greater acceptance in Japan than in the U.S. However, after having been challenged in the marketplace by their international competitors, U.S. firms sought the help of these same consultants in the area of quality management. Three people led the development of the current set of management tools within TQM: 1) Dr. W. Edwards Deming; 2) Dr. Joseph Juran; and 3) Philip B. Crosby.

2.3.1.1 Deming and TQM

To successfully practice TQM in a firm, top managers must take the first step, accepting and committing to the guidelines and points that form the basis of TQM. The firm can then begin to implement TQM using the Deming wheel which breaks down all actions into a continuing process of four interlinked steps: plan-do-check-act. This keeps the firm moving along a path of continuous improvement, driven by the need to identify and eliminate waste and variance in any form. Deming maintained that the keys are teamwork, training the work force, and committed leadership of top management. Deming's 14 points describe his management philosophy (see Table 2.1).

Table 2.1. Deming's 14 Points for Quality

1. Create constancy of purposes for the improvement of product and service.
2. Adopt the new philosophy.
3. Cease dependence on mass inspection.
4. End the practice of awarding business based on the price tag alone.
5. Improve constantly and forever the system of production and service.
6. Institute job training and retraining.
7. Institute leadership.
8. Drive out fear.
9. Break down all barriers between staff areas.
10. Eliminate slogans, exhortations, and targets for the work force.
11. Eliminate numerical quotas.
12. Remove barriers to pride of workmanship.
13. Institute a vigorous program of education and retraining.
14. Take action to accomplish the transformation.

Source: Walton, M. (1986). *The Deming Management Method*, New York: Putnam, 55-88.

2.3.1.2 Juran and TQM

After Deming, Dr. Joseph Juran had the greatest impact on the theory and practice of quality management. Juran's concepts have promoted the development of the theory and practice of TQM by beginning on the shop floor and working up to the level of top management. He

describes today's quality transformation within businesses as a shift from "little Q" to "big Q" (Juran and Gryna 1993). Businesses that practice "little Q" traditionally focus their quality efforts on the physical product or service provided to their ultimate customers. The movement today is toward "big Q", which extends the application of quality concepts to all functional activities by recognizing that each associated process has both internal and external customers. Juran bases his philosophy of quality on three managerial processes: 1) quality planning; 2) quality control; and 3) quality improvement. Juran's philosophy is referred to as the "Quality Trilogy" and Table 2.2 shows the activities that each of these managerial processes requires.

Table 2.2. Juran's Quality Trilogy

Quality Planning	**Quality Control**	**Quality Improvement**
Establish quality goals	Choose control subjects	Prove the need
Identify customers	Choose units of measure	Identify projects
Learn customer's needs	Set goals	Organize project teams
Develop product features	Create a sensor	Diagnose the causes
Develop process features	Measure performance	Provide remedies
Develop process controls	Interpret the difference	Deal with resistance to change

Source: Juran, J.M., and Gryna, F.M. (1993). *Quality Planning and Analysis*, 3rd ed., New York: McGraw-Hill, 9.

2.3.1.3 Juran vs. Deming

Juran and Deming shared similar points of view on many subjects. Like Deming, Juran refined many of his quality theories while working with Japanese companies. Both agreed on the important role of top managers in TQM, and both recognized a crisis of quality in manufacturing. Both also agreed on the importance of both internal and

external customers, the importance of continuous improvement, and the need for effective training and tools.

However, these two pioneers viewed some aspects of TQM from different perspectives. For example, Deming is more process oriented while Juran is more concerned about the output. Deming focused on statistical process control, and Juran espoused the concept of total quality control. Other noteworthy differences include (Melnyk and Denzler 1996):

- Deming believed that everyone within the firm (including operating employees) must contribute to successful implementation of TQM; Juran emphasized middle managers as key players in this change.
- Deming set a goal of perfect quality; Juran advocated accepting lower quality if the benefits of achieving perfection would not justify the costs.
- Juran focused on the quantitative costs more than Deming, who emphasized more subtle indicators of quality.
- Deming identified variance as the target of TQM initiatives; Juran tolerated variance more willingly.

In many ways, Juran continued and extended traditional ways of thinking about quality while Deming advocated a break with tradition and a new approach to quality management. It is thought that Deming's work with the Japanese had the most immediate and profound effect on Japanese quality, whereas Juran's activities provided the framework for integrating quality concepts throughout the organization.

2.3.1.4 Crosby and TQM

Philip B. Crosby, the third major influence on the management tools of TQM, believed that in order for an organization to change from traditional quality management to an innovative and enduring quality management process, it must understand four absolutes of quality management, which are designed to answer four important questions (see Table 2.3).

Table 2.3. Crosby's Absolutes for Quality Management

1. *What is quality?* The definition of quality is conformance to requirements, not goodness.

2. *What system do we need to institute so that we offer a quality product or service?* The system of quality is prevention, not detection.

3. *Which performance standard should we use to measure the quality of our performance?* The performance standard is zero defects, not "that's close enough."

4. *Which system is appropriate for measuring the quality of what we do?* The measurement of quality is the price of nonconformance.

Source: Crosby, P.B. (1984). *Quality Without Tears: The Art of Hassle-Free Management*, New York: McGraw Hill, 58-86.

Following Deming, Crosby addressed his message to top management. In quality management, he saw a viable strategy for corporate survival and growth. Further, he denied that a firm must invest large sums to improve quality; rather, such investments save money. As a result, Crosby asserted, a quality management program will generate savings that ultimately will pay for itself. This line of reasoning leads to Crosby's conclusion that, ultimately, quality is free.

Crosby advocated a more ambitious goal than simply eliminating problems through improved inspections. Rather, managers should strive for a goal of zero defects. They should design and build products with the objective from the outset of generating products without any defects. Crosby urged managers to set a corporate tone that denies the inevitability of defects, which contrasts his position with Juran.

Like Deming and Juran, Crosby advocated a continuing process of TQM and urged elimination of quality-related defects and creation of a

quality-oriented corporate culture. Finally, Crosby also stressed the importance of top management's role (Melnyk and Denzler 1996).

Crosby differed from Deming and agreed with Juran in his view that managers play more important roles than workers. Crosby also accepted slogans, mottoes, and posters as both appropriate and useful which Deming criticized. Finally, Crosby advocated performance measures and goals, while Deming called for an elimination of work standards and numerical quotas.

2.3.1.5 TQM: A Summary

While Deming, Juran, and Crosby have disagreed on details, they offer a unified message on certain important themes. These themes form the basic tenants or beliefs of TQM:

- Quality is not tactical but strategic in nature.
- Quality is necessary to corporate survival and growth.
- Quality is not the responsibility of one functional group or area. Rather, quality is a corporate responsibility in that every area has an impact on the level of quality ultimately delivered by the firm's operation management system.
- Quality is not defined by the firm; it is defined by the customer and fulfilled by the firm.
- To best appreciate the full impact of poor quality, it is necessary to capture and measure all of the effects created by lack of quality.
- The most effective approach to quality is prevention, not appraisal.
- To affect quality, the process by which quality is generated must be understood and changed.
- Quality requires continuous improvement; we can never deliver too much quality.
- Effective quality requires management support and commitment and action by the employees responsible for delivering quality.
- Improved quality is the result of a corporate culture which is organized around and committed to quality.
- For people to do their tasks more effectively, management must supply them with access to the appropriate tools. Furthermore, management must also provide them with adequate education and training in the use of these tools.
- Quality is a process.
- The importance of quality cannot be allowed to be compromised by short term considerations or actions.

These pioneers have devoted considerable attention to identifying key practices that impact quality. These individuals use their personal experiences to discuss the reasons for inferior quality of U.S. products and have recommended prescriptions for TQM such as management leadership, customer focus, and shop floor quality control. They use their experiences to better explain the superior operational performance of firms that incorporated these quality practices. Unfortunately, anecdotal evidence which is based on personal experiences, while providing insights into the critical constructs associated with TQM, cannot generalize the prescriptions.

2.3.2 Empirically-Based Research

Early empirical studies focused mostly on comparisons of quality management practices in the U.S. and Japan (Garvin 1984, 1986; Ebrahimpour 1985, 1988). These studies concluded that the Japanese are more proactive, giving a very high priority to top management support, long-range planning, and shop floor control. The U.S. tendency was to inspect quality into the product after it was built.

Empirical research has also focused on the relationship between various quality management programs and quality performance, and between overall firm performance (Garvin 1986; Roth, De Meyer, and Amano 1990; Miller and Roth 1994). However, only a limited number of quality management practices were included in these studies. Also, none of these empirical studies identify and validate the constructs associated with TQM. Most of the empirical research examining the effect of TQM on business performance has been conducted by consulting firms or quality associations with a vested interest in their outcomes. All of these studies did not conform with generally-accepted standards of

methodological rigor, as well as being subject to a host of experimental confounds and biases (Powell 1995). Examples include: 1) the Union of Japanese Scientists and Engineers (JUSE) study (1983); 2) a New York Conference Board study (1989); 3) a U.S. Government General Accounting Office (GAO) report (1993); the International Quality Study (American Quality Foundation 1991), a joint project conducted by Ernst & Young (an accounting and consulting firm), and the American Quality Foundation (the research arm of the American Society for Quality Control); and 4) an Arthur D. Little, Inc., report (1992). The difficulty of measuring the impact of TQM on corporate profitability has also been noted in several studies (Bowels and Hammond 1991; Evans 1992; Hiam 1992).

Only a few published studies have developed and empirically validated instruments for operationalizing the constructs associated with TQM. Saraph, Benson, and Schroeder (1989) pioneered efforts to identify and empirically validate TQM constructs. This was the first empirical study which resulted in an instrument for measuring the effectiveness of TQM constructs. Saraph et al. developed a model of quality management practices, and measured managers' perceptions of eight critical factors of quality management at the business unit level. Using divisional quality managers as respondents, they gathered responses about the importance of various constructs. The response sample of 162 managers spanned both the manufacturing and service sector, and included 20 firms. Cronbach's coefficient alpha was used for scale refinement. Construct validity was assessed using principal components factor analysis on each construct. In addition, content validity and criterion-related validity were established. A major strength of their measurement instrument was the high level of external

validity achieved by sampling from both manufacturing and service industries.

The Saraph et al. study draws primarily from the principles advocated by quality gurus such as Deming, Crosby, and Juran. Their instrument derived constructs primarily using the prescriptions of quality gurus rather than also using the empirical literature. It also excluded two major constructs (i.e., customer focus and statistical process control), and demonstrated tautologies among various scales. For example, the item "commitment of the divisional top management to employee training" in the Training construct captured some of the domain of the Role of Divisional Top Management and Quality Policy construct. Such tautologies can result in artificially biased correlations among constructs (Ahire, Golhar, and Waller 1996).

A more recent study which attempted to develop a theoretical framework using the practitioner and empirical literature is provided by Flynn, Schroeder, and Sakakibara (1994). It represented a significant departure from the Saraph et al. study. For example, the instrument was administered at the plant level rather than business unit level. Through a comprehensive literature review, they identify 6 main "programs" within TQM that lead to continuous improvement of manufacturing capability: 1) Quality Information; 2) Process Management; 3) Product Design; 4) Workforce Management; 5) Supplier Involvement; and 6) Customer Involvement. They propose that the TQM effort begins with Top Management Support, which leads to emphasis being placed on the 6 quality elements. Another key difference between their effort and others is that they attempted to triangulate on the quality and performance constructs by sampling from different levels within a

firm; top management, staff, and production floor people are all sampled using appropriate instruments.

The secondary thrust of Flynn et al.'s effort was the development and validation of an appropriate research instrument (to validate the theoretical constructs). The resulting instrument measured 7 dimensions appropriate to investigating world class quality: 1) Top Management Support; 2) Quality Information; 3) Process Management; 4) Product Design; 5) Workforce Management; 6) Supplier Involvement; and 7) Customer Involvement. Note that, employee empowerment and benchmarking scales were not found in their measurement instrument. Also, higher customer involvement may reflect poor quality management practices and not the amount of customer focus (Ahire, Golhar, and Waller 1996). Regardless, a set of 14 perceptual scales were developed and tested by 716 respondents at 42 plants across the transportation, electronics, and machinery manufacturing industries. Thus, as compared to the Saraph et al. study, the focus of this study was on the manufacturing sector. Due to its multiple industry orientation, the Saraph et al. instrument has greater external validity. Both the Saraph et al. and Flynn et al. instruments followed the general confirmatory factor analysis approach for scale validation. However, Cronbach's coefficient alpha was used more rigorously for scale refinement by Flynn et al. Each scale was refined until the aggregate response sample, as well as various strata of the sample (e.g., Japanese-owned plants and U.S.-owned plants), exhibited satisfactory alpha values for the scales.

A recent study of the implementation of TQM criteria is also one of the most comprehensive. Taking the position that TQM can be treated as a "strategic resource" for the firm, Powell (1995) develops a survey

instrument that measures a firm's TQM "implementation progress," its TQM "program performance," and five business performance indicators. The instrument uses 12 common "TQM Factors" developed as a composite from the TQM literature. This study used an archival analysis of popular perspectives on TQM. The study compared the approaches of Deming's 14 Points, The Juran Trilogy, and Crosby's 14 Quality Steps, and identified 12 factors common to all as a surrogate measure of TQM. It is very similar to the Saraph et al. study in that the constructs are primarily derived from the prescriptions of quality gurus rather than also using the empirical literature.

Survey respondents were asked to self-report their implementation status on each of the 12 factors: Executive Commitment, Adopting the Philosophy, Closer to Customers, Closer to Suppliers, Benchmarking, Training, Open Organization, Employee Empowerment, Zero-Defects Mentality, Flexible Manufacturing, Process Improvement, and Measurement. Only Cronbach's coefficient alpha was computed to test the reliabilities of the TQM scales. General approaches for scale validation such as confirmatory factor analysis were not used.

2.3.3 Formal Assessment Processes

Quality management is a continuing process and never accepts its current version as definitive. Its critical importance requires vigilant protection from compromises driven by short-term considerations or actions. Daily detail can overshadow the more distant goals of TQM unless some formal system sets clear the specifications for quality as a standard for routine activities and as a basis for competition. International and national programs like ISO 9000 and the Malcolm Baldrige National Quality Award (MBNQA) define such specifications

(Reimann and Hertz 1994; Curkovic and Handfield 1996; Melnyk and Denzler 1996).

In the past, organizations have treated quality management primarily as a management decision in which managers determine the level of quality that their firm will offer and then sell to appropriate customers. Increasingly, however, government agencies, customers, and the firms themselves have come to recognize the potential importance of quality. This increased awareness of quality has inspired two recent developments: 1) ISO 9000 and 2) the Malcolm Baldrige National Quality Award (MBNQA). These international and national programs have formalized systems for evaluating the ability of any firm to consistently design, produce, and deliver a quality product. In this section, the implications of these important standards for TQM are explored. It begins with an examination of ISO 9000, proceeds to discuss the MBNQA, and then finishes by comparing the two programs.

2.3.3.1 ISO 9000

The ISO 9000 series of quality standards was developed by the International Standards Organization (ISO) in 1987, and has since become the international quality standard (Watson 1992). The series was adopted by the European Community (EC) without change and is published as the European Norm (EN) 29000 series (American National Standards Institute 1987). One feature of the EC union is the selection of a single standard of assurance that a product was produced in a quality-controlled production process. This standard, ISO 9000, is similar to a contract between a purchaser and supplier - assurance that a product was produced in a quality controlled production process. Compliance of an organization to the standard is monitored by independent third parties.

ISO 9000 identifies the basic attributes of a manufacturer's quality management system and specifies practical procedures and approaches to ensure that its products and services are produced in accordance with the process standards specified by the firm. The ISO 9000 series is actually made up of five separate standards: 1) ISO 9000; 2) ISO 9001; 3) ISO 9002; 4) ISO 9003; and 5) ISO 9004.

ISO 9001, 9002, and 9003 are models (that is, conformance standards for quality assurance systems) and relate to supplier-customer relationships. ISO 9000 and 9004 are guidelines and relate to the development of quality systems within the company. ISO 9001 is the most comprehensive and applies to facilities that design, develop, produce, install, and service their own products. ISO 9002 applies to firms that provide goods or services consistent with the specifications furnished by the customer. ISO 9003 applies to final inspection and test procedures only.

ISO 9000 registration requires a series of steps which in turn affect organizational structure. First, a firm determines which standards in the series are applicable to its situation. Next, a company-specific quality manual is developed, which provides a specific set of policies related to the implementation of quality standards. Finally, a full assessment follows, executed by an independent on-site team that verifies: 1) there is a procedure in place to measure quality; 2) there is a review process to monitor quality; and 3) there are qualified staff to carry out these policies.

The American National Standards Institute (ANSI)/American Society for Quality Control (ASQC) Q90-94 standards are technically equivalent to the ISO 9000-9004 series, but incorporate customary American language

usage and spelling. The ISO 9000 standards focus on 20 specific aspects of a quality program. All of these 20 aspects are covered in Section 4 of the ISO 9000 document and are listed in Table 2.4.

Table 2.4. 20 Aspects Covered in Section 4 of ISO 9000

1. Management Responsibility
2. Quality System
3. Contract Review
4. Design Control
5. Document Control
6. Purchasing
7. Purchasing of Supplied Product
8. Product Identification and Traceability
9. Process Control
10. Inspection and Testing
11. Inspection, Measuring, and Test Equipment
12. Inspection and Test Status
13. Control of Nonconforming Products
14. Corrective Actions
15. Handling, Storage, Packaging, and Delivery
16. Quality Records
17. Internal Quality Audits
18. Training
19. Servicing
20. Statistical Techniques

Source: Breen M., Jud, B., and Pareja, P.E. (1993). *An Introduction to ISO 9000*, Dearborn, MI: Society of Manufacturing Engineers, Reference Publication Division, 2.

Perhaps the best way to recognize the character of the ISO 9000 process is to relate it to the concept of TQM. ISO 9000 describes and defines the fundamental nature of the work processes necessary for an organization to achieve the objectives of TQM (Reimann and Hertz 1994; Curkovic and Handfield 1996). Thus, ISO 9000 is a critical first step in implementing a TQM system. ISO 9000 implementation forces managers to reexamine all their business processes, and identify any discrepancies between what employees are actually doing and what the

documentation states should be done. In cases when a discrepancy exists, there are three possible actions: 1) retrain appropriate employees, with respect to their process activities; 2) change the documentation to reflect what employees are actually doing; and 3) reengineer the entire process, retrain the employees, and change the documentation.

Because of the growing acceptance of ISO 9000 as a common standard of quality assurance, it has been adopted by various industries as a pre-qualifying criteria for awarding business (Curkovic and Pagell 1997). For example, many regard the adoption of QS 9000 and ARD 9000, which are derivations of ISO 9000, by the automotive and aerospace industries respectively, as an affirmation of the principles behind the ISO 9000 quality standards (Eastman 1995; Ridley 1997). Seeing the European standards accepted and used by such large and influential manufacturers has encouraged others to adopt and adapt the ISO 900 standards for their purposes (Avery 1995). American software companies are currently preparing for the Japanese software specifications called JIS Z9901 which are based on ISO 9000 (Zuckerman 1995). Even NASA now requires its suppliers to be ISO 9000 certified, as does the department of defense (Karon 1996). The National Science Foundation has also developed a specialized quality program for the food and beverage industries which are also based on the quality management system requirements of ISO 9000 (Kerr 1996).

2.3.3.2 The Malcolm Baldrige National Quality Award (MBNQA)

In 1987, former President Ronald Reagen signed the Malcolm Baldrige National Quality Improvement Act. The act established an annual national award to recognize quality improvement among

manufacturing, service, and small businesses. The act did not describe the scoring system, judging process, or criteria for evaluating applications. The examination criteria were developed by a group of recognized quality professionals who volunteered their services to establish the operational statement of quality. The examination criteria have to some extent been interpreted as an operational definition of TQM, and the wide distribution of the application guidelines has exposed many managers to the MBNQA definition of TQM. Since that time, the MBNQA criteria have often been cited as a template for establishing a thorough TQM system. One of the important outputs of the award is the creation and diffusion of useful TQM practices. Over 180,000 applications were distributed in 1991 alone.

The MBNQA was established for three primary reasons. One reason was to raise the consciousness of U.S. business leaders regarding the issue of quality. Another reason was to provide a comprehensive framework for measuring the quality efforts of U.S. businesses. Lastly, it was established to provide U.S. businesses with a template for a thorough TQM system (Hockman 1992).

The MBNQA encourages organizations to address quality on a broad range of issues. Companies that wish to compete for the award must produce evidence of leadership and long-term planning, initiate verifiable quality control procedures, address the happiness and well-being of the work force, and, above all, work toward customer satisfaction. The criteria argue strongly for customer-driven organizations, high levels of employee involvement, and information-based management. For companies not competing for the award, the

application provides a framework for implementing a quality program and establishes the benchmarks for measuring future progress.

The award criteria are subject to review, and have evolved and changed over the last several years. A wide range of stakeholders such as judges, examiners, companies that have applied for the award, and members of leading trade associations, are surveyed annually and asked for their advice on how the criteria can be improved. Continuous improvement is also the most basic and important tenant of the MBNQA criteria. In each of the 20 major criteria items, companies are asked how they plan to improve in that area. The criteria are both process and results oriented. The award criteria are intended to address many company operations, processes, strategies, and requirements.

While the process to receive the award lasts one year from the time of application to the time of award announcement, it typically takes a company 8 to 10 years to develop a quality system that is competitive for the award (Handfield and Ghosh 1994). The Baldrige Award is composed of seven separate, weighted categories: 1) leadership: 2) strategic planning; 3) customer and market focus; 4) information and analysis; 5) human resource development and management; 6) process management; and 7) business results.

These categories are described in detail in Table 2.5. A total of 1,000 points are possible on the application. To be a contender for the award, a company should be capable of scoring above 700 points. The top companies, with scores of 700 or more, typically have balanced and outstanding performance across the board. The highest score to date on a MBNQA application has been in the mid-800 point range (Hockman 1992). Each company that applies for the MBNQA receives a feedback report that

describes the findings of the Board of Examiners relative to the company's strengths as well as its areas for improvement.

Table 2.5. The Malcolm Baldrige National Quality Award

1.0 **Leadership** (110 points): The *Leadership* category examines senior leaders' personal leadership and involvement in creating and sustaining values, company directions, performance expectations, customer focus, and a leadership system that promotes performance excellence. Also examined is how the values and expectations are integrated into the company's leadership system, including how the company continuously learns and improves, and addresses its societal responsibilities and community involvement.

- 1.1 Leadership System (80 points)
- 1.2 Company Responsibility and Citizenship (30 points)

2.0 **Strategic Planning** (80 points): The *Strategic Planning* category examines how the company sets strategic directions, and how it determines key action plans. Also examined is how the plans are translated into an effective performance management system.

- 2.1 Strategy Development Process (40 points)
- 2.2 Company Strategy (40 points)

3.0 **Customer and Market Focus** (80 points): The *Customer and Market Focus* category examines how the company determines requirements and expectations of customers and markets. Also examined is how the company enhances relationships with customers and determines their satisfaction.

- 3.1 Customer and Market Knowledge (40 points)
- 3.2 Customer Satisfaction and Relationship Enhancement (40 points)

4.0 **Information and Analysis** (80 points): The *Information and Analysis* category examines the management and effectiveness of the use of data and information to support key company processes and the company's performance management system.

- 4.1 Selection and Use of Information and Data (25 points)
- 4.2 Selection and Use of Comparative Information and Data (15 points)
- 4.3 Analysis and Review of Company Performance (40 points)

5.0 **Human Resource Development and Management** (100 points): The *Human Resource Development and Management* category examines how the work force is enabled to develop and utilize its full potential, aligned with the company's objectives. Also examined are the company's efforts to build and maintain an environment conducive to performance excellence, full participation, and personal and organizational growth.

- 5.1 Work Systems (40 points)
- 5.2 Employee Education, Training, and Development (30 points)
- 5.3 Employee Well-Being and Satisfaction (30 points)

Table 2.5. The Malcolm Baldrige National Quality Award (continued)

6.0 **Process Management** (100 points): The *Process Management* category examines the key aspects of process management, including customer-focused design, product and service delivery processes, support processes, and supplier and partnering processes involving all work units. The category examines how key processes are designed, effectively managed, and improved to achieve better performance.

- 6.1 Management of Product and Service Processes (60 points)
- 6.2 Management of Support Processes (20 points)
- 6.3 Management of Supplier and Partnering Processes (20 points)

7.0 **Business Results** (450 points): The *Business Results* category examines the company's performance and improvement in key business areas - customer satisfaction, financial and marketplace performance, human resource, supplier and partner performance, and operational performance. Also examined are performance levels relative to competitors.

- 7.1 Customer Satisfaction Results (130 points)
- 7.2 Financial and Market Results (130 points)
- 7.3 Human Resource Results (35 points)
- 7.4 Supplier and Partner Results (25 points)
- 7.5 Company-Specific Results (130 points)

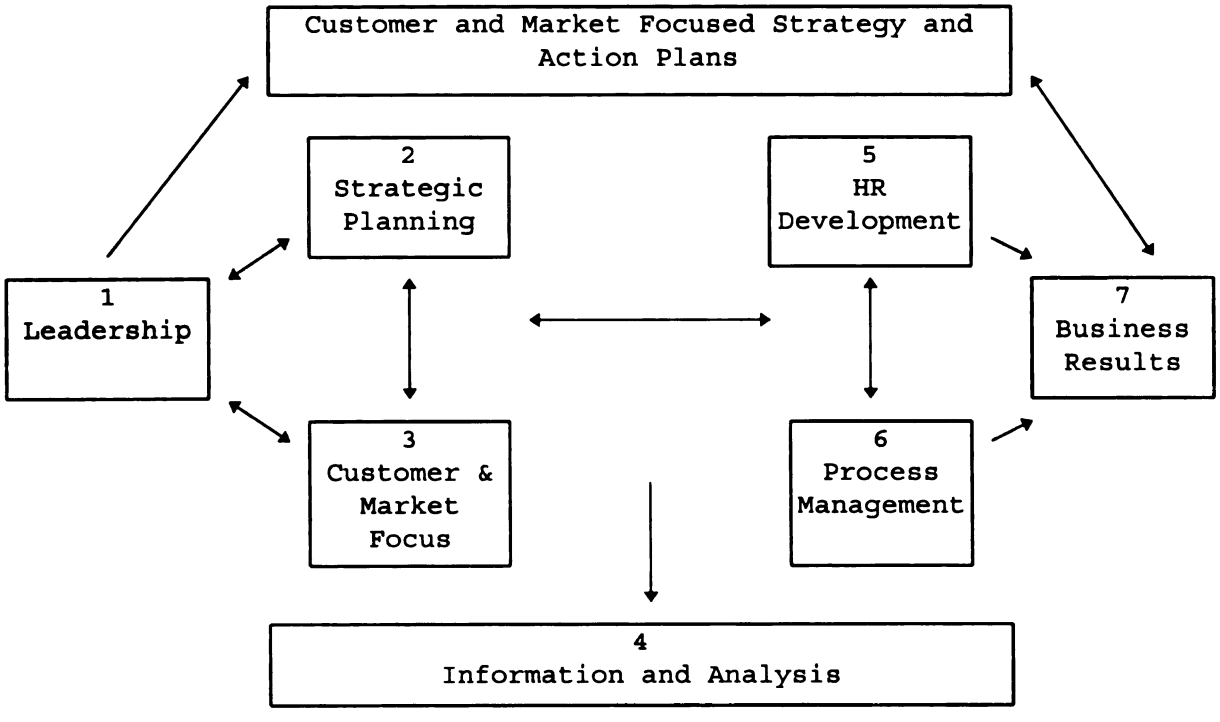
Source: *Malcolm Baldrige National Quality Award 1997 Award Criteria.* (1997). Milwaukee, WI: The Malcolm Baldrige National Quality Award Consortium, Inc.

Every two years, the MBNQA criteria are reviewed for potentially major revisions. Suggestions for revisions and improvements are solicited each year from examiners, judges, winners, and applicants. The 1997 revisions represent possibly the most significant changes in the Award's 10-year history. Even more than the 1995 revision, the term "quality" is conspicuously absent throughout the criteria. The Award booklet states, "The Criteria continue to evolve toward comprehensive coverage of strategy-driven performance, addressing the needs and expectations of all stakeholders - customers, employees, stockholders, suppliers, and the public."

The most noticeable changes are the criteria framework, which places greater importance on company strategy to treat all business

results in an integrated manner, and new renumbering of the categories. The new framework treats customer and market-focused strategy and action plans as the umbrella that guides overall business decisions and aligns work units within the organization. The "system" is viewed as three related subsystems (Evans 1997): 1) the "strategic" categories of leadership, strategic planning, and customer/market focus; 2) the "operational" categories of human resource development and management and process management (which leads to "results"); and 3) the "information and analysis" category that serves as the foundation for the other two subsystems. Figure 2.1 describes the relationship between the categories.

Figure 2.1. THE MALCOLM BALDRIGE NATIONAL QUALITY AWARD CRITERIA



2.3.3.3 ISO 9000 versus the MBNQA

So far in this section, two formal search methods designed to improve and assure quality have been presented. A comparison of the MBNQA and ISO 9000 coverage is summarized in Table 2.6. Studies have demonstrated that the MBNQA criteria are more comprehensive than the ISO 9000 standards in assessing quality improvement (Reimann and Hertz 1994; Ahire, Landeros, and Golhar 1995; Curkovic and Handfield 1996). A closer look at both sets of criteria reveals that satisfying the basic ISO 9000 standard typically is less difficult than scoring well on the MBNQA criteria (Curkovic and Handfield 1996). The ISO 9000 international standard is somewhat of a common denominator in the field of quality, which provides assurance that an organization's policies and procedures are being followed in practice. However, many U.S. firms are under the misconception that ISO 9000 registration is the foundation for a TQM program. The ISO 9000 criteria are really a subset of requirements for full implementation of a TQM program. ISO 9000 certification ensures that a quality system is in place, but does not guarantee the functionality of that system. The ISO standards take the form of conformance instruments for existing quality systems and are not as broad as the MBNQA to act as a framework for the TQM field. For example, the MBNQA addresses competitive factors such as customer and market focus, results orientation, and continuous improvement which are either not addressed in the ISO standards or are addressed differently.

Table 2.6. A Comparison of the MBNQA and ISO 9000 Coverage

MBNQA Items Covered by ISO 9000	MBNQA Items NOT Covered by ISO 9000
Senior executive leadership	Public responsibility
Management for quality	Competitive comparisons and benchmarks
Scope and management of quality and performance data information	Analysis and uses of company-level data
Human resource management	Quality and performance plans
Employee education and training	Employee involvement
Employee performance & recognition	Employee well-being and morale
Design and introduction of quality products and services	Quality assessment
Process management - product and service delivery processes	Product and service quality results
Process management- business process and support services	Company operational results
Supplier quality and results	Business process and support service results
Future requirements and expectations of customers	Customer relationship management
	Commitment to customers
	Customer satisfaction determination,
	Continuous Improvement

Source: Curkovic, S., and Handfield, R.B. (1996). "Use of ISO 9000 and Baldrige Award Criteria in Supplier Quality Evaluation," *International Journal of Purchasing and Materials Management*, Spring, 9.

Companies in the early stages of TQM development should view the ISO 9000 initiative as a first step in the evolution of a fully developed quality system. ISO 9000 provides guidelines which link certification requirements to quality-related corporate issues, and can be useful for companies in the initial stages of a TQM program who are attempting to map out their business processes. Such an approach not only qualifies an organization to operate in the EC and other international markets, it also prepares the organization for applying the MBNQA application criteria. Following ISO 9000 certification, organizations should then pursue the implementation of a more fully integrated TQM program using the MBNQA application as a template for business process reengineering and continuous improvement. The MBNQA

provides a comprehensive framework within which to conduct a total quality audit for all functions within the organization.

2.4 An Operational Framework of TQM

The beginning of this chapter offered several definitions of TQM. A series of associated traits were identified from these definitions of TQM: 1) continuous improvement; 2) meeting customers' requirements; 3) long-range planning; 4) increased employee involvement; 5) process management; 6) competitive benchmarking; 7) team-based problem-solving; 8) constant measurement of results; 9) closer relationships with customers; and 10) management commitment. Using these traits, the various constructs found in the three categories of frameworks were reviewed to determine which framework best fits the definition of TQM (see Table 2.7).

Table 2.7. The Best Definitions of TQM

Associated Traits of TQM	Juran	Deming	Crosby	Saraph et al. (1989)	Flynn et al. (1994)	Powell (1995)	ISO 9000	MBNQA
Continuous Improvement	X	X	X	X	X			X
Meeting Customer's Requirements	X	X			X	X	X	X
Long-Range Planning	X			X				X
Increased Employee Involvement	X	X	X	X		X		X
Process Management		X		X	X	X	X	X
Competitive Benchmarking				X		X		X
Team-Based Problem-Solving	X		X	X		X		X

Table 2.7. The Best Definitions of TQM (continued)

Associated Traits of TQM	Juran	Deming	Crosby	Saraph et al. (1989)	Flynn et al. (1994)	Powell (1995)	ISO 9000	MBNQA
Constant Measurement of Results	X		X	X	X	X	X	X
Closer Relationships with Customers	X	X			X	X		X
Management Commitment	X	X	X	X	X	X	X	X
10 Traits Total:	8	6	5	8	6	8	4	10

A series of 10 traits were identified by going back to the definitions of TQM at the beginning of the chapter (Section 2.2). These traits were identified based on the TQM definitions by Evans (1992), Logothesis (1992), and Melnyk & Denzler (1996). Using the traits associated with TQM, and comparing these traits to the various constructs found in the literature, the MBNQA framework best fits the definition of TQM. Since the MBNQA framework is most consistent with the definition of TQM, it will be used as the operational framework of TQM for the purposes of this dissertation research. Many other researchers have also adopted the MBNQA framework as the basic operational model of TQM -- Dean and Bowen (1994) used it to explore the relationship between the principles of TQM and management theories; Black and Porter (1996) used it to develop their TQM survey questions; and Capon, Kaye, and Wood (1994) used it to identify measures of TQM success.

2.5 TQM: A Stepping Stone to Major Developments Such as ERM

Ferdows and DeMeyer (1990) showed that quality management practices are associated with improvements in the largest number of performance indicators - not only with those related to quality itself, but also those related to dependability, flexibility, and cost. Quality management practices positively impacted all four capabilities and were the only management practices that impacted other capabilities. These researchers challenged the longheld assumption that achieving strength along one capability should come at the expense of the rest. This pattern of cumulative returns has been referred to as the "sandcone model."

Since TQM is regarded as an integrated set of quality management practices (Ross 1993), TQM itself can be a stepping stone to building cumulative capabilities. Leading practitioners of TQM, such as Motorola and Xerox, have demonstrated cumulative returns along capabilities in terms of quality, dependability, flexibility, and cost. Recognizing its cumulative building capabilities, practitioners of TQM have been able to use it as a foundation for major developments such as time based competition and mass customization (Blackburn 1991; Carter and Melnyk 1992; Pine 1993).

A similar relationship between TQM and Environmentally Responsible Manufacturing (ERM) has been suggested. Although originally applied to operations management for the purpose of improving product quality (i.e., reducing product waste in time, materials, and labor), the concept of TQM is being translated to the realm of ERM. It has been suggested by several researchers, through mostly conceptual analyses and case studies, that significant benefits arise from applying what has

been learned about TQM to environmental issues (Habicht 1991; Alm 1992; Friedman 1992; Post and Altman 1992; Wheeler 1992; Klassen and McLaughlin 1993; Makower 1993; Neidart 1993; Thompson and Rauck 1993; Woods 1993; Willig 1994; Hanna and Newman 1995; May and Flannery 1995; Sarkis and Rasheed 1995; Epstein 1996; Rodinelli and Berry 1997).

For example, Klassen and McLaughlin (1993) suggested the need for an empirical investigation which examines whether firms which have advanced TQM programs in place also have more advanced environmental management programs than firms just initiating TQM. A case study analysis by Post and Altman (1992) identified that a firm's ability to reframe learnings from quality management programs is crucial to being environmentally responsible. Eastman Kodak, a former recipient of the MBNQA, has already begun to apply the principles of TQM to its environmental management program. Some researchers, such as Makower (1993) and Willig (1994), bring together first hand reports on how leading companies are going beyond meeting regulatory compliance to gaining competitive advantage and improved profitability by applying TQM practices to ERM. In these studies, the authors describe how the implementation of ERM can be made more successful by integrating it into a TQM system.

These examples assume there is a relationship between TQM and ERM. Namely, it is suggested that TQM systems, by their presence, encourages the emergence and acceptance of ERM. However, this argument remains untested. The research presented in this dissertation will clarify much of the confusion surrounding the assumed relationship between TQM and

ERM. The next section introduces ERM as the next main body of literature to be discussed.

2.6 Environmentally Responsible Manufacturing

Any meaningful discussion of the principles and practices of Environmentally Responsible Manufacturing (ERM) requires a definition of what it is, an identification of its primary traits, and a discussion of its importance. Many different labels are used to describe companies' efforts to integrate environmental thinking into their decision-making processes. For example, Industrial Ecology, Environmental Operations Management, Environmentally Conscious Manufacturing, and Environmentally Responsible Manufacturing are among the most popular labels used. However, a close examination of these terms highlights that they differ mostly by their labels and not in definition.

Arthur D. Little (1991) discussed the concept of Industrial Ecology which involves designing industrial infrastructures as if they were a series of interlocking man-made ecosystems interfacing with the natural global ecosystem. Industrial Ecology takes the pattern of the natural environment as a model for solving environmental problems, creating a new paradigm for the industrial system in the process.

Environmental Operations Management (EOM) has been defined as the integration of environmental management principles with the decision-making process for the conversion of resources into usable products (Gupta and Sharma 1996). EOM is viewed as a strategic level of operations management since it primarily concerns product and process design. EOM requires a thorough assessment of the operations of a firm, from the purchase of various inputs (e.g., raw materials and energy) through process control and changes (e.g., air and water pollution

control, waste disposal operations, and new pollution control technology) to the output itself (e.g., green and clean products).

Sarkis and Rasheed (1995) defined Environmentally Conscious Manufacturing (ECM) as involving planning, developing, and implementing manufacturing processes and technologies that minimize or eliminate hazardous waste and reduce scrap. A major objective of ECM is to design products that are recyclable or can be remanufactured or reused.

Melnyk and Handfield (1996) define Environmentally Responsible Manufacturing (ERM) as a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing its effect on the environment while also trying to maximize resource efficiency. Compared to the other labels and definitions used to describe the integration of environmental issues into decision-making processes, ERM is the most comprehensive and perhaps salient. Therefore, ERM and its definition described earlier will be used for the purposes of this dissertation. Associated with this definition are nine important assumptions and premises which identify the primary traits associated with ERM.

- **ERM decisions are always present and are integrated into the business process.** There is a tendency for managers to see the implementation of ERM as a matter of choice. However, every manufacturing decision made regarding products and/or processes involves ERM. Decisions can also be explicit or implicit. For example, the redesign of a process so that it creates less hazardous waste would be an explicit decision. When managers select a specific process or operating technology because it can help generate higher quality goods with less lead time and at lower costs, they also implicitly accept the environmental affects attributable to it.

- **The ultimate goal of ERM is waste elimination.** Pollution is the expenditure of energy without the offsetting generation of value;

therefore, pollution itself should be characterized as a form of waste (Juran 1978; Porter 1991). Viewed in this light, an obvious extension of the TQM principle of waste elimination is the elimination of unproductive waste entering the environment (e.g., pollution)(Klassen and McLaughlin 1993).

- **ERM must be strategically evaluated using a cost/benefit analysis in order to be successfully implemented.** Currently, there are two general approaches to ERM. The first is that the requirement for ERM is imposed externally, by government regulatory agencies. Since the requirement is driven by political and social considerations, it is difficult to justify any investments in ERM other than those dictated by compulsory regulations. These type of firms do just what is necessary to satisfy the regulations. The second approach to ERM is to regard it as a business decision with long-term implications. The extent to which a company adopts ERM can affect the strategic and cost position of a firm. As a result, ERM decisions must be strategically evaluated using a cost/benefit analysis (Bemowski 1991; Stratton 1991; Porter and Van der Linde 1995a, 1995b; Epstein 1996).

- **Effective ERM must focus on products, processes, and packaging.** There are three potential areas in which ERM decisions must be recognized and taken: 1) product (e.g., how it is designed, the materials used in it, the environmental impacts of its use and disposal); 2) process (e.g., how the product is made); and 3) packaging (e.g., the protective materials used in delivering components to the process or in delivering the product to the customer). However, this perspective should not ignore support facilities (e.g., tank farms and waste water treatment), given that some of the greatest costs and pollution comes from these sources.

- **ERM must be integrated into the system of product and process development and design.** The ultimate goal of ERM is to reduce and eliminate environmental waste. This can only be achieved when environmental issues are integrated with the early stages of product and process design (Allenby 1993; Graedel and Allenby 1995).

- **ERM is a holistic endeavor.** The benefits of ERM extend beyond waste reduction. ERM creates a safer working environment for employees which makes the firm more attractive to employees and investors. In addition, ERM has a significant positive affect on other stakeholders such as the community and regulatory agencies (Bronstein 1989; Epstein 1991, 1996; Gutfield 1991; Rosewicz 1990).

- **ERM is ultimately a cross-functional undertaking.** ERM affects all of the functional areas of a business enterprise (Kleiner 1991; Post 1991). ERM brings together people from different functional areas to uncover, assess, and solve environmental problems. Typically, this requires participation from: 1) engineering (e.g., product, process, manufacturing, industrial); 2) marketing (to assess market/customer response and demands); 3) manufacturing; 4) cost accounting (to assess the costs associated with ERM decisions); 5) human resources

(people must be involved in ERM); 6) purchasing (acquisition and disposal of waste); 7) legal (to assess the legal implications of new regulations and actions being considered by the firm); and 8) middle and top level management (to assess the strategic impacts of ERM decisions). A separate and distinct department for ERM can cause other parts of the organization to ignore ERM issues since "someone else" is responsible for them.

- **ERM recognizes the implications of the supply chain for the achievement of its objectives.** The overall success of ERM is greatly influenced by the actions of its suppliers (Johannson 1994). While not yet commonplace, many companies are including ERM issues in discussions with suppliers. ERM procurement policies can be implemented to reduce cost, minimize risk, and reduce liability. Enforcement of these policies is important; suppliers who cannot show a degree of responsibility in this area can prove to be a serious liability and costly to the purchaser of a product or service (Finn 1994). Yet, for many firms, the supply chain represents a major challenge, since they may not have the ability to directly influence or monitor the environmentally related actions of suppliers.

- **ERM is dynamic.** ERM is greatly influenced by political and social issues (e.g., government regulations). These factors are often beyond the control of the firm. As a result, the standards and requirements that help define what is minimally acceptable from an environmental perspective should be viewed as dynamic. What was once considered leading-edge ERM yesterday may become minimally accepted today and unacceptable tomorrow.

ERM has become an important factor in the decision-making process of companies around the world. Traditional ways of dealing with environmental issues in a reactive, ad-hoc, end-of-pipe manner, have proven to be highly inefficient (Global Environmental Management Initiative 1996). However, ERM is not just a legal or moral obligation. ERM makes very good business sense. Reducing pollution means increasing efficiency and wasting fewer resources. Improved health and safety conditions result in a more productive workforce. Supplying goods and services that respect the environment helps to expand markets and improve sales. In short, companies become more competitive when they practice ERM.

ERM in corporations has grown substantially in both size and importance, and the significance of their decisions has increased dramatically (Epstein 1996). Many companies (e.g., Proctor & Gamble, DuPont, Monsanto, etc.) are reorganizing functional responsibilities, engaging the most senior executive in environmental oversight, elevating decision-making about environmental issues, spending substantial amounts of money to go well beyond compliance laws, and redesigning whole systems of resource use and production. There are many reasons why numerous companies have begun to take ERM very seriously. Some of the reasons for this increased attention include: criminal and civil liabilities, the fear of exposure as an obstructionist polluter, concern to attract environmentally conscious engineers and scientists, a sense of responsibility to neighbors, and customers are demanding it (Arthur D. Little, Inc. 1992). The competitive position of a company is strongly impacted by its response to environmental issues (Bavaria 1995). By properly implementing an ERM system, any company, large or small, can ensure that they effectively manage environmental risks while identifying and exploiting the opportunities ERM can bring (Global Environmental Management Initiative 1996).

Substantial competitive advantages can also be achieved through ERM. Expected benefits of ERM include safer and cleaner facilities, lower future costs for disposal and worker protection, reduced environmental and health risks, and improved product quality at lower cost and higher productivity (Sarkis and Rasheed 1995). Companies have come to recognize that reduced environmental impacts and the institutionalization of ERM can lead to improved operations and profitability (Epstein 1996).

2.7 Categories of Frameworks

Research on ERM issues published in refereed journals, practitioner publications (e.g., Newsweek), and books and monographs were identified for the purposes of this dissertation research. Increased attention was given to ERM articles in refereed academic journals because of the rigorous review that these papers go through prior to publication. However, ERM is an emerging field that has not been researched widely within academia. Because ERM issues did not receive much attention prior to the 1970s, the search was restricted to articles published since this time. Only after 1970 did ERM start receiving acceptance as an important topic. The following procedure was used to identify the ERM literature:

1. An exhaustive list of keywords related to the topic area was compiled (e.g., environmental management, environmentally responsible manufacturing, industrial ecology, environmental regulations, etc.). The list provided for an adequate search to identify the articles in the area of ERM.

2. The primary emphasis for the search was to identify articles with a management focus rather than having a technical or engineering orientation. The ABI-INFORM computerized database was the major database used to identify ERM articles. The ABI-INFORM database was used for two major purposes: 1) ABI would ensure a comprehensive coverage of the ERM field; and 2) ABI identifies the major keywords associated with each reference which drove the classification scheme.

3. The internet and website pages were also used to identify working papers and conference proceedings to identify unpublished ERM articles.

4. Each article identified in steps 2 and 3 were reviewed. Any article whose focus was on environmental issues was classified as an ERM article. Only those articles written outside the context of environmental issues were eliminated from further consideration and were not classified as ERM articles.

5. The bibliographies of the articles passing step 4 were also used to identify any other relevant articles which may have been missed in the computerized search. Again, for any newly independent articles, step 4 was repeated. Relevant ERM articles in journals found during the cross-reference that were not included during the computerized search were also added to the database of ERM articles.

This procedure ensured a comprehensive examination of the body of literature as it pertained to the ERM field. The intention was to exhaustively review the ERM literature. The only factor that might have prevented the accomplishment of this goal is that the review focused on the field of management and eliminated some technically oriented articles which focused on engineering issues. With very few other limitations, over 10,000 references were identified for examination. These 10,000 references were collected and pooled into an ERM database.

Three different categories of frameworks emerged from the literature: 1) anecdotal; 2) empirically-based research; and 3) formal assessment processes. The first category focuses on corporate success stories and the personal experiences of environmentalists such as Cairncross and Makower. The empirically-based research category looks at applied studies which mostly chart a continuum of approaches that companies display toward ERM. The third and final category examines popular formal assessment processes developed by the International Standards Organization, Global Environmental Management Initiative, and Council of Great Lakes Industries. These three categories of frameworks are used to identify the various views of the constructs associated with ERM and the items which represent manifestations of these constructs.

2.7.1 Anecdotal

Over 75% of the articles in the ERM database appeared in the popular press literature and were anecdotal in nature. These articles focused on corporate success stories and firms that promoted ERM policies and programs. They point out the need for companies to adopt a

proactive posture if they are to maintain a competitive advantage and respond to a powerful green consumer movement (Ferguson 1989; Zetlin 1990). Consistent themes in these proactive companies were top management commitment to ERM and the implementation of policies and programs which are both environmentally responsible and cost-effective. Frequently cited in this literature are the successes of firms such as:

- Browning-Ferris Industries (Awareness & Compliance Tools for Environmental Responsibility)
- Union Carbide (Audit Timeliness Index)
- Dow Chemical (Waste Reduction Always Pays)
- McDonald's (Waste Reduction Action Plan)
- Xerox (Asset Recycle Management)
- Minnesota Mining & Manufacturing - 3M (Pollution Prevention Pays)

A number of new books also emerged during the early 1990s which probe even deeper into industry's role in ERM. Each book provides a slightly different perspective and offers prescriptions for how ERM should evolve. These books are similar in their focus on creating a sustainable future. Vice-President Al Gore (1993) sings the praises of ERM by arguing that it is often the best way to increase a company's efficiency, and therefore, profitability. Gore outlines an environmental plan called the "Marshall Plan," with the primary objective being the creation of a sustainable society. His strategy under the "Marshall Plan" impacts the corporate sector directly by emphasizing industry's need to create and develop environmental technologies.

Cairncross (1992) differs from Gore in that industry's role in ERM is not treated in isolation from the government. Cairncross stresses the role of government agencies to create alliances with industry. Cairncross discusses how policies such as product standards and

government-industry alliances can be used to foster sustainable development. Cairncross advocates the government's role in designing more innovative environmental policies which support both economic growth and a cleaner environment. The book concludes with a checklist for companies to follow. It includes managerial actions such as: 1) a clear and publicly communicated environmental policy; 2) active tracking of energy consumption and waste creation; and 3) accepting that environmental regulations will continue to escalate and that acting prior to them becoming compulsory will provide a competitive advantage.

Schmidheiny (1992) also explores industry's role in achieving sustainable development; however, the economic aspects of ERM are explored in much greater detail than offered by Cairncross and Gore. According to Schmidheiny, technological changes are required which was Gore's major point; however, Schmidheiny points out that changes in the goals and assumptions that drive corporate activities, and changes in the tools used to reach them are also required. Specifically, Schmidheiny explores full-cost pricing, self-regulation, energy use, and capital markets. Similar to Gore's "Marshall Plan" and Cairncross' "checklist", Schmidheiny articulates how sustainable development should be integrated into corporate operations. It includes values such as: 1) there can be no economic growth unless it is environmentally sustainable; 2) products, services, and processes all must contribute to a sustainable world; 3) open dialogue with stakeholders is critical; 4) innovative environmental practices are achieved through voluntary initiatives rather than compulsory regulation; and 5) employees are evaluated and rewarded for their contributions to sustainable development.

Stead and Stead (1992) also explore the economic aspects of ERM similar to Schmidheiny. They call for a new economic paradigm which includes the environment as a critical component, so that corporate managers can begin to integrate the environment into their strategic decision-making. They point out the difficulties associated with achieving sustainability, noting specifically the physical, social, and cultural barriers.

Each of these books provides a slightly different perspective and prescriptions for how ERM should evolve. However, similar themes include: 1) radical calls for changing business/societal/government relations concerning the environment; 2) the need for new economic frameworks which account for environmental costs; and 3) an acknowledgment that a few "best practices" companies are achieving sustainable development, but most companies need much more improvement. While these books provide an overview of how corporations need to change, Makower (1993) explores internal corporate operations in more depth and how environmental issues affect all areas of a company's activity. Makower stressed that environmental factors encompasses many parts of a business, from the things they make, to the things they buy, to the relationships they have with their employees, suppliers, customers, regulators, the media, and the communities in which they do business.

Makower (1994) also argued that environmental issues affect all of the functional areas of a business enterprise, including the management of human resources, operations, research and development, marketing, and strategic positioning. Strategic and operating decisions are both affected on a daily basis. Managerial decisions about products,

environmental, health and safety standards, and business lines are major decisions. The commitment to ERM cannot be met, according to Makower, without addressing all of these dimensions of corporate activity.

Makower's books also offer a slightly different perspective on sustainability. The other authors did not emphasize the environment as an economic opportunity. Makower's books deal with incorporating environmental issues into decision-making processes throughout a company's operations in both environmentally friendly and profitable ways. Makower stresses that incorporating environmental issues into decision-making processes can be economical and ecological. Another important theme that distinguishes his books is the link he makes between the environment and quality. Makower looks at the common themes between environmental management and TQM. One of the most important connections Makower makes is that in the pursuit of quality, the goal is to continually decrease waste, pollution, defects, and inefficiencies. Considering that waste and pollution are defects (in that they result from inefficiencies in the system), Makower follows that an ultimate goal of environmental quality is to achieve zero waste and pollution.

2.7.2 Empirically-Based Research

Most of the applied studies in the ERM literature chart a continuum of approaches that companies display toward ERM issues. The research has suggested two different perspectives on patterns of ERM: 1) a set of choices along a spectrum; and 2) a developmental progression. A strategic perspective implies that distinct choices are made among a set of alternatives, whereas a developmental progression proposes a managed expansion or growth over time. For example, Vastag, Kerekes, and Rodinelli (1996) present a framework to evaluate corporate

ERM strategies based on a survey of 141 companies in Hungary. In the proposed framework, a company's environmental risks are analyzed on two dimensions: 1) endogenous (arising from internal operations); and 2) exogenous (e.g., location, ecological setting, demographic characteristics). Four ERM approaches are defined as a function of the endogenous and exogenous environmental risks: 1) reactive; 2) proactive; 3) strategic; and 4) crisis preventive. The study concludes that implementing a strategic ERM approach may not be the best option for all companies - although there is growing pressure to do so. Vastag et al. argue that although international standards such as ISO 14000 often imply that a strategic approach to developing and implementing an ERM program is appropriate for all companies, it may not be necessary or financially possible for companies with low levels of environmental risk to move from proactive or crisis preventive approaches to strategic approaches.

Arthur D. Little, Inc. (1989) developed a three-phase framework of ERM approaches based on a decade long analysis of U.S. companies in various industries. During the first phase (problem-solving), burdensome costs are avoided and surprise elements often have catastrophic cost ramifications. In the second phase (managing for compliance), the company emphasizes current compliance but does not provide for future liability. In the last stage (managing for assurance), significant investment is made in environmental assurance even though it may have limited financial payoff. The developmental progression perspective described in this study is designed to represent the stages of progress a company would typically experience in developing ERM programs. Companies are argued to meet the criteria of

one level before they have significant activities for the next level. Each performance level incorporates the cumulative descriptions of all prior performance levels. A summary of the empirical ERM studies is presented in Table 2.8.

Table 2.8. Empirical Studies Characterizing ERM

Strategic Choice Perspective	**Stages**
Mahon, J.F. (1983)	1) avoid/neglect; 2) resistance; 3) accomodative; 4) compromise; and 5) collaborative
Logsdon, J.M. (1985)	1) resisting; and 2) accepting
Miles, R.H. (1987)	1) collaborative/problem-solving; and 2) individualistic/adversarial
Schot, J. (1991)	1) dependent; 2) defensive; 3) offensive; 4) aware; and 5) adapted
Arnfalk, P, & Thidell, A. (1992)	1) passive; 2) authority-controlled; 3) law-optimized; 4) aware; and 5) adapted
Dillon, P.S., & Fischer, K. (1992)	1) good environmental actors; and 2) bad environmental actors
Klassen, R.D. (1995)	1) reactive; 2) defensive; 3) accomodative; and 4) proactive
Vastag, G., Kerekes, S., and Rondinelli, D.A.(1996)	1) reactive; 2) proactive; 3) strategic; and 4) crisis preventive
Handfield, R.B, Walton, S.V., Seegers, L.K., & Melnyk, S.A. (1997)	1) resistance adaptation; 2) embracing w/o innovating; 3) reactive; 4) receptive; 5) constructive; and 6) proactive
Developmental Progression Perspective	**Stages**
Petulla, J.M. (1987)	1) crisis oriented; 2) cost oriented; and 3) enlightened
Arthur D. Little, Inc. (1989)	1) problem-solving; 2) managing; and 3) managing for assurance
Hunt, C.B., & Auster, E.R. (1990)	1) beginner; 2) fire-fighter; 3) (1990) concerned citizen; 4) pragmatist; and 5) proactivist

Table 2.8. Empirical Studies Characterizing ERM (continued)

Developmental Progression Perspective	Stages
Clarkson, M. (1991)	1) reactive; 2) defensive; 3) accomodative; and 4)proactive
Marguglio, B.W. (1991)	1) insensitivity; 2) awareness; 3) enlightenment; and 4) certainty
Greening, D.W. (1992)	1) high involvement; and 2) low involvement
Post, J.E., & Altman, B.W. (1992)	1) adjustment; 2) adaptation; and 3) innovation
Flannery, B., & May, D.R. (1994)	1) individual; and 2) organizational
Greenberg, R., & Unger, C. (1994)	1) innocence; 2) awareness; 3)understanding; 4) competence; and 5) excellence
Epstein, M.J. (1996)	1) corporate environmental leader --- 7) corporate environmental laggard

The research literature is clearly divided on whether distinct strategies are used or whether firms evolve through a progression of stages. Logsden (1985) and Klassen (1995) both point out that the lack of a definitive answer is due in part to very few longitudinal empirical studies (Logsdon 1985). Klassen uses the strategic perspective as his theoretical basis because the developmental perspective ideally requires a longitudinal analysis; however, the research does support both perspectives. Studies agree that that an upwards of 50% of firms are located near the middle of the development cycle, still in a state of transition and ongoing development (Arthur D. Little 1989; Petulla 1987). The Arthur D. Little study places 10-15% of companies in their

first and last stages. Hunt and Auster (1990) do not cite specific percentages, but conclude that most corporations are still in a reactive mode and that few corporations are at the proactive stages. Most of these continuum studies conclude that the majority of corporations are in transition between different phases, generally moving away from reactive toward proactive strategies.

While very few of the continuum studies attempt to determine causal relationships with for example ERM performance and management methods, they all help identify positive characteristics associated with ERM firms. All of these continuum studies attempt to identify the necessary programmatic components of environmentally progressive companies. Major areas of overlap between these studies on recommended managerial approaches include: 1) experienced and strong leadership abilities of environmental managers; 2) top management commitment; 3) integration of environmental issues into corporate policies; 4) existence of a written policy statement; 5) long-term environmental planning process; 6) incorporation of environmental factors into standard operating procedures; 7) communication mechanisms between environmental staff and management; 8) strong environmental auditing programs; 9) involvement of environmental professionals into business planning; and 10) educated employees with established ownership of environmental problems.

While many similar managerial practices are identified in the continuum studies, they fall short in explaining the processes which organizations go through to make changes and how the managerial practices identified fit into these processes. Unfortunately, many adherents of ERM embrace the philosophy without understanding either its

impact on short- and long-term management practices in their organizations or the extent of the commitment required at all levels (Makower 1993). In fact, it appears that the ERM applications have preceded the theoretical framework. Only recently have researchers used empirical studies to examine ERM implementation in detail (Epstein 1996). The ERM field has yet to establish a theoretical and empirical base. Only a few empirical studies have undertaken hypothesis generation and theory testing (Klassen 1995; Vastag et al. 1996). However, to transform ERM into a formal, rationally evaluated discipline, additional empirical research in this direction is required.

Thus far, only one empirical study has resulted in instruments for measuring the effectiveness of ERM constructs (Klassen 1995). Furthermore, not all of the important constructs were identified. However, this is the only empirical study which identifies and validates the ERM constructs. Scale development and validation are required so that a proven instrument can be used in subsequent empirical research on integrated ERM strategies to develop and test causal models of ERM implementation effectiveness. Klassen draws upon very current and comprehensive scale validation techniques used in the marketing and social sciences literature to yield more reliable scales. ERM was operationalized using 3 multi-item, seven-point scales corresponding to the 3 factors of planning/systems analysis, organizational structure, and management controls. Internal reliability was assessed and individual items were eliminated based on a three-step procedure similar to that used in earlier scale development for information technology and strategy (Sethi and King 1994; Venkatraman 1989). These steps were based on scale development techniques used in marketing (Churchill 1979)

and other social sciences (Bagozzi 1981a, 1981b; Sethi and King 1994). First each factor was tested individually for internal reliability, otherwise called unidimensionality using Cronbach's coefficient alpha. Then an overall 3 factor confirmatory factor model was assessed using a latent variable measurement model (LISREL). This complex methodology was used to model this 3 factor construct because the factors were expected to be highly correlated. The inter-factor correlation could be estimated and explicitly tested as a measure of convergent validity. Finally, discriminant validity was assessed with the 3 factors.

2.7.3 Formal Assessment Processes

The risks associated with managing environmental issues requires that it not be dealt with on an ad-hoc basis. As with quality management, only a properly implemented management approach can provide protection from short-term actions which are not well-founded. Daily details can impede an organization's longer-term environmental goals unless some formal environmental management system clearly sets the requirements as a standard for daily activities. By properly implementing an appropriate environmental management system, a company can ensure that they more effectively manage environmental risks. Such a systematic approach to environmental management is at the heart of formal international and national assessment processes. The increased importance of managing environmental risks has inspired formal assessment processes developed by the International Standards Organization, Global Environmental Management Initiative, and Council of Great Lakes Industries. In this section, the implications of these organizations and their formal assessment processes on ERM are explored.

2.7.3.1 International Standards Organization

Representatives from some 50 countries around the globe have recently agreed to the draft international standard (DIS) on environmental management systems (ISO/DIS 14001) issued by the International Standards Organization (ISO). The draft was formally adopted in 1996. It is intended that the implementation of an environmental management system (EMS) based on this standard will result in improved environmental performance. The standard is based on the concept that the organization will periodically review and evaluate its EMS in order to identify opportunities for improvement and their implementation. Improvements in its EMS are intended to result in additional improvements in environmental performance. When the ISO standard is fully adopted, it is anticipated that existing national EMS standards, such as BS 7750 (UK), IS 310 (Ireland), NF X30-200 (France), and UNE 77-801(2)-94(Spain) will be withdrawn and replaced by the single international EMS standard. Adoption by the European Council of ISO 14001 as the standard to implement Council Regulation EEC/1836/93 on a Community Environmental Management and Audit Scheme (EMAS) is not yet decided.

ISO/DIS 14001 is one of a series of emerging international environmental management standards aimed at promoting continual improvement in company environmental performance through the adoption and implementation of an EMS. The standard specifies the core elements of an EMS, but contains only those elements that may be objectively audited for certification. A companion guidance standard, ISO/DIS 14004 includes examples, descriptions, and options that aid in the implementation of an EMS and in integrating the EMS into overall

management practices. It is not intended for use by certification/registration bodies. ISO/DIS 14001 defines an overall environmental management system, closely modeled on the ISO 9000 quality systems standard. The key elements of ISO 14001 are covered in Table 2.9.

Table 2.9. Elements of ISO 14001

- **Establishment of an appropriate environmental policy** that is documented and communicated to employees and made available to the public, and which includes a commitment to continual improvement and pollution prevention, regulatory compliance and a framework for setting objectives.

- **A planning phase** that covers the identification of the environmental aspects of the organization's activities, identification and access to legal requirements, establishment and documentation of objectives and targets consistent with the policy, and establishment of a program for achieving said targets and objectives (including the designation of responsible individuals, necessary means and time frames.

- **Implementation and operation of the EMS** including the definition, documentation, and communication of roles and responsibilities, provision of appropriate training, assurance of adequate internal and external communication, written management system documentation as well as appropriate document control procedures, documented procedures for operational controls, and documented and communicated emergency response procedures.

- **Checking and corrective action procedures**, including procedures for regular monitoring and measurement of key characteristics of the operations and activities, procedures for dealing with situations of non-conformity, specific record maintenance procedures and procedures for auditing the performance of the EMS.

- **Periodic management reviews of the overall EMS** to ensure its suitability, adequacy, and effectiveness in light of changing circumstances.

Source: *Global Environmental Management Initiative.* (1996). ISO 14000 Environmental Management System Self-Assessment Checklist, GEMI: Washington, D.C., March.

In many aspects, the ISO 14001 standard shares common management system principles with the ISO 9000 series of quality system standards.

In the beginning of the ISO 14001 standard, it states that "organizations may elect to use an existing management system with the ISO 9000 series as a basis for its EMS." It should be understood, however, that the application of various elements of the management system may differ due to different purposes and different interested parties. While quality management deals with customer needs, environmental management systems address the needs of a broad range of interested parties and the evolving needs of society for environmental protection. Also, regulation will certainly always play a stronger role in driving environmental programs than it does quality programs.

The ISO 14000 family of standards also includes other draft standards related to environmental management systems that will soon be available for trial. These include standards on environmental auditing and related environmental investigations, environmental labeling, environmental performance evaluation, life-cycle assessment, terms and definitions and environmental aspects in product standards.

2.7.3.2 The Global Environmental Management Initiative

The Global Environmental Management Initiative (GEMI) is a group of 28 companies dedicated to fostering environmental excellence by business worldwide. It was founded in 1990 with the goal of promoting ERM. GEMI is generally credited as being the first organization to marry ERM and TQM. The group developed an assessment primer in 1993 which has taken the principles associated with TQM and applied them to ERM to provide a systematic approach and methodology for continuous improvement in environmental performance. The primer outlines methods of applying TQM to corporate ERM programs, a process GEMI has identified as Total Quality Environmental Management (TQEM). Numerous companies

have instituted a TQEM approach to improving their ERM programs, including McDonald's, Xerox, Proctor & Gamble, and 3M (Makower 1994; Epstein 1996).

The primer begins by explaining the elements of a TQEM system, including identifying your customers, continuous improvement, doing the job right the first time, and taking a systems approach to work. The primer then describes how to build a TQEM system within a business. This involves assessing your status in terms of environmental opportunities, learning to use P-D-C-A, and learning to use TQEM tools (e.g., cause and effect diagrams, pareto charts, control charts, flow charts, histograms, benchmarking). GEMI suggests that the goal of TQEM is to establish a corporate culture in which continuous improvement is the norm, so that the entire system works toward the multifaceted goal of meeting or exceeding all customers' requirements and anticipating their future needs.

In 1992, in an effort to continue progress in improving the ERM programs of companies, GEMI produced an Environmental Self-Assessment Program (ESAP) designed by the management consulting firm of Deloitte & Touche. The Environmental Policy Center and Law Companies Environmental Group also assisted in its development. The ESAP provides a checklist of elements of an ERM program targeted at the International Chamber of Commerce's (ICC) Business Charter for Sustainable Development. The 16 principles, published by the ICC, provide a comprehensive assessment framework for promoting sustainable development in business, and are carefully designed to assist companies in improving their ERM programs. The 16 ICC principles are listed in Table 2.10.

Table 2.10. ICC's Business Charter for Sustainable Development

1. Corporate Priority
2. Integrated Management
3. Process of Improvement
4. Employee Education
5. Prior Assessment
6. Products and Services
7. Customer Advice
8. Facilities and Operations
9. Research
10. Precautionary Approach
11. Contractors and Suppliers
12. Emergency Preparedness
13. Transfer of Technology
14. Contributing to the Common Effort
15. Openness to Concerns
16. Compliance and Reporting

The ESAP claims that a company will progress through a series of stages when developing ERM programs to implement the 16 ICC principles. The descriptions of the stages focus on the ERM program and the extent to which it has been integrated into general business processes in the company. The ESAP suggests that companies should generally meet the criteria of one level before they have significant activities for the next level. These stages include: Level 1) Compliance Stage; Level 2) Systems Development and Implementation Stage; Level 3) Integration into General Business Functions Stage; and Level 4) Total Quality Approach Stage.

2.7.3.3 The Council of Great Lakes Industries

In 1994, the Council of Great Lakes Industries (CGLI) also developed a TQEM primer and self-assessment matrix for companies to improve their ERM programs. To serve companies with a less-developed ERM programs, the matrix serves as a quantitative self-assessment tool, and as a guide to develop an ERM program from the ground-floor up.

The CGLI program is based on seven categories adapted from those used in the Malcolm Baldrige National Quality Award (MBNQA) competition. Although the MBNQA annually recognizes U.S. corporations that excel in quality management and achievement, the process that underlies the award can be applied globally to measure and guide continuous improvement in all business areas, including ERM.

The CGLI team of industry specialists involved in this project spent nearly a year adapting the original MBNQA matrix to ERM. The categories within the matrix include: 1) leadership (15%); 2) information and analysis (7.5%); 3) strategic planning (7.5%); 4) human resource development (10%); 5) quality assurance of environmental performance (15%); 6) environmental results (30%); and 7) customer/stakeholder satisfaction (15%). Each category has 10 levels of implementation, ranging from beginning (Level 1) to growing (level 5) to maturing (Level 10), and each category is weighted based on the above percentages. In the late 1980s, these criteria were incorporated into a matrix framework by a team within Eastman Kodak Company. The matrix is used by that company as a rating system that provides an indication of the company's strengths and improvement opportunities. In the TQEM assessment matrix, the CGLI team adapted the 7 MBNQA categories so they more fully relate to TQEM; their definitions are shown in Table 2.11.

Table 2.11. The Council of Great Lakes Industries TQEM Categories

Leadership: senior management's success in creating the TQEM values and in building these values into the way the company operates.
Information and Analysis: the effectiveness of the company's collection, analysis, and use of information for environmental planning and improvement.
Strategic Planning: the effectiveness of the company's integration of its customer/stakeholder environmental requirements into its business plans.
Human Resources Development: the success of the company's efforts to realize the full potential of its work force in implementing TQEM.
Quality Assurance of Environmental Performance: the effectiveness of the company's systems for assuring TQEM, with emphasis on continuous improvement and prevention.
Environmental Results: the company's improvements in TQEM and demonstration of TQEM excellence, based on quantitative measures.
Customer/Stakeholder Satisfaction: the effectiveness of the company's systems in determining customer/stakeholder environmental requirements, and its demonstrated success in meeting them.

CGLI describes the TQEM model as beginning and ending with customers and stakeholders. Knowing what they expect drives the development of systems that improve performance so that their needs can be better satisfied. This requires leadership and commitment from senior management. Only then can a company commit the resources needed, or speak with one voice. Once a company has senior management buy-in, then it begins to gather information (e.g., about customer/stakeholder needs, risks, costs, benefits), and to channel this information into its strategic planning. Through planning, goals and objectives are set and measures for success are selected. None of this can be done without the appropriate involvement of people (human resource development), whose teamwork and consensus is needed to successfully implement improvement

programs. A system of checks and balances, or quality assurance systems, provide review/feedback loops to continuously improve the overall system. These activities will move the company closer to its goal of achieving a level of performance that will satisfy the expectations of its customers and stakeholders, thus closing the loop and bringing the company full circle.

2.7.3.4 A Comparison of Formal Assessment Processes

The GEMI ESAP and ISO 14000 standards are aimed at determining to what extent a company adheres to its vision and principles. The relationship between the ICC Business Charter Principles (which the GEMI ESAP is based on) and ISO 14001 elements is shown in Table 2.12.

Table 2.12. ICC Business Charter Principle vs. the ISO 14001 Elements

ICC Principles	ISO 14001
1. Corporate Priority	XX
2. Integrated Management	XX
3. Process of Improvement	XX
4. Employee Education	XX
5. Prior Assessment	
6. Products and Services	
7. Customer Advice	
8. Facilities and Operations	X
9. Research	
10. Precautionary Approach	X
11. Contractor and Suppliers	X
12. Emergency Preparedness	XX
13. Transfer of Technology	
14. Contributing to the Common Effort	
15. Openness to Concerns	XX
16. Compliance and Reporting	XX

XX ISO 14001 element equivalent to ICC Principle
X ISO 14001 has minimal coverage
Blank ISO 14001 does not cover

Source: *ISO 14001 Environmental Management System Self-Assessment Checklist*. (1996). Global Environmental Management Initiative: Washington, D.C.

The CGLI TQEM Primer is not aimed at determining to what extent a company adheres to its vision and principles. The GEMI ESAP and ISO 14000 standards already exist for these applications. Although some improvement in environmental performance can be expected due to the adoption of the ISO 14000 standards, it should be understood that it is a tool which enables the organization to achieve and systematically control the level of environmental performance that it sets for itself. Assessment programs to evaluate conformance with guiding principles or practices is at the heart of GEMI's assessment program for the Sustainable Development Principles of the International Chamber of Commerce. Tools such as GEMI's ESAP and the ISO 14000 standards complement the management system assessments described in the CGLI TQEM Primer. They are much less comprehensive and therefore, not a substitute for them. In addition to a step-by-step guide, the CGLI TQEM Primer also includes a list of detailed questions that an internal auditor/assessor can use to identify gaps in management systems and processes, as well as opportunities for improvement. In summary, a realization of a company's vision and guiding principles depends on the establishment and functioning of a fundamentally sound underlying management system which is embodied in the CGLI TQEM Primer.

2.8 Drawing Parallels Between TQM and ERM

The parallels between TQM and ERM have been drawn by numerous researchers (Habicht 1991; Alm 1992; Friedman 1992; Wheeler 1992; Makower 1993; Klassen and McLaughlin 1993; Neidart 1993; Thompson and Rauck 1993; Willig 1994; May and Flannery 1995; Epstein 1996). They all point out that both TQM and ERM: 1) aim to improve a company's final output; 2) require some new definitions of leadership; 3)

emphasize long-range planning over short-term considerations; 4) involve changing relationships between companies and their employees, suppliers, and customers; 5) strive for a cultural change; 6) stress improved information, communication, training, and accountability; and 7) demand continual self-assessment and improvement.

The purpose of this section is to review the links between the concepts of TQM and ERM in detail. Several concepts from the TQM literature will be reviewed, and parallels will be drawn with ERM. Having already identified the traits associated with TQM, and having compared these traits to the various constructs found in the literature, it was determined that the MBNQA framework best fits the definition of TQM (see Section 2.4). Since the MBNQA framework is the most consistent with the definition of TQM and is used as the operational framework of TQM for the purposes of this dissertation research, the 7 categories associated with the framework will be used to draw parallels between TQM and ERM. Parallels are drawn to show that the operational framework of TQM can be adapted for ERM.

2.8.1 Leadership

Senior management acts as a driver of TQM implementation; establishing values, goals, and systems to satisfy customers' needs and expectations and improve organizational performance. Several authors who have researched several diverse organizations have concluded that senior executives must provide a vision of customer orientation, clear and visible quality values, and high performance expectations (Ham and Williams 1986; Kennedy 1989). Other authors have also asserted that through constant personal involvement, senior executives must reinforce

quality values in their organizations (Juran 1978, 1981a, 1981b; Tregoe 1983).

The critical guide and motivator for the development and implementation of ERM must also come from senior management (Arthur D. Little, Inc. 1989; Hunt and Auster 1990; Schot 1991; Epstein 1996). Often, a cultural change is necessary within management to purge the concept that waste and pollution are inevitable (Bemowski 1991). Adopting ERM requires a fundamental change in the way an organization does business; therefore, a buy-in is required from senior management to create a cultural change within the organization (Wever and Vorhaur 1993). ERM requires that management is directly involved in ERM processes as a leader and role model (Makower 1993). Senior managers cannot delegate this leadership role away. They need to demonstrate personal commitment to the company's vision and principles and to "walk the talk", if others are to follow their lead (CGLI 1994).

2.8.2 Strategic Planning

TQM requires that product quality be defined from the customer's viewpoint. Exceeding the customer's expectations can only be accomplished when organizations strategically plan and organize their resources (Ahire, Landeros, and Golhar 1995). Strategic quality planning requires that an organization integrate all key quality requirements into overall business plans. The most important step in strategic quality planning is to find out what the customer expects from the organization. Garvin (1987) defined quality along eight dimensions: performance, features, conformance, reliability, durability, serviceability, perceived quality, and aesthetics. Each organization must assess its capability to incorporate a subset of these dimensions

of quality into each product. A more structured quality-oriented organization leads to more effective efforts toward increased quality (Dale and Duncalf 1985). The interfunctional nature of strategic planning for quality is demonstrated by numerous researchers (Juran 1978; Wheelwright 1981; Garvin 1987). TQM requires that quality becomes part of the annual business plan, with corporate and divisional goals, and performance is subject to annual review (Juran 1981b).

ERM is becoming a strategic issue as well (Klassen and McLaughlin 1993). The strategic planning process ensures that: 1) ERM issues will become an integral part of planning; and 2) a process will be in place to communicate with customers and stakeholders and include their input in planning (Wever and Vorhauer 1993). Based on the eight dimensions of quality highlighted earlier, one recommendation is to compete strategically on a subset of quality dimensions, tied directly to current corporate strengths and customer expectations (Garvin 1987). One important dimension is the response to customer and stakeholder demands about the environmental impacts of products during and after use (Klassen and McLaughlin 1993). Similar to the interfunctional nature of quality, all systems involved in the production, delivery, circulation, use, and disposal of products must be analyzed to confirm that they have no adverse effect on the environment (Mizuno 1988). Reinforcement of this cradle-to-grave approach is already embodied in the U.S. in the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments (Herod 1989). To develop this strategic orientation, ERM goals must also become part of the annual business plan with an annual performance review to track progress (Hunt and Auster 1990; Epstein 1996).

2.8.3 Customer and Market Focus

TQM is based on the premise that the customer is always right. In fact, quality is defined as what the customer wants. This category encompasses an organization's knowledge of its customers, overall customer service system, responsiveness, and ability to meet customer requirements and expectations. However, the focus of TQM is both internal and external customers. The definition of customer has been addressed in several papers (Baum 1990; Feldman 1991). These researchers extended the definition to include employees as internal customers and suggested that such an extension would reduce departmental factionalism (Ahire, Landeros, and Golhar 1995). Supplier development and quality purchasing have also been underscored as an integral part of TQM (Juran and Gryna 1988). Studies have examined customer satisfaction from the point of view of the buyer-seller relationship, to see if customers' needs and expectations are addressed by producers of intermediate goods (Ishikawa 1985; Lascelles and Dale 1989a). Their conclusions were that manufacturing and suppliers are interdependent and quality can be purchased into a product to a significant degree.

ERM also requires the adoption of response systems to handle the most basic of customer/stakeholder concerns or requirements. As the company progresses to higher levels, it is required to become more proactive, to anticipate customer/stakeholder expectations and concerns, and to measure the extent to which it has satisfied those needs (CGLI 1994). Most ERM programs focus initially on regulatory agencies as their primary external customers (GEMI 1996). Although many managers believe that nothing can be done until regulators are satisfied, ERM requires that all customers be identified and satisfied. Customers may

be diverse as local communities, or as specific as the PTA of the school down the street. Similar to TQM, in which researchers extended the definition of customers to include employees as internal customers, ERM defines the functions and processes within a company as internal customers and suppliers (GEMI 1996). The overall success of ERM is also greatly influenced by the actions of its suppliers. While not yet commonplace, many companies are including ERM issues in discussions with suppliers (Johannson 1994). For example, in 1989, Metro Toronto initiated a program to include environmental considerations in their purchasing policy and championed a coordinated effort with various levels of government to address procurement's contribution to ERM. Enforcement of such policies is important; suppliers who cannot show a degree of responsibility in this area can prove to be a serious liability and costly to the purchaser of a product or service.

2.8.4 Information and Analysis

Fundamental to TQM is collecting relevant information from all phases of an organization's operations and using it to monitor and improve quality. In the context of TQM, information technology (hardware) and systems (software) design must provide useful information to decision makers to improve an organization's quality performance. The importance of the expanded role of information technology and systems in integrating information from inside and outside the company (e.g., suppliers, customers, competitors) has been identified in the literature (Willborn 1986; Riehl 1988). In other words, information management must be viewed as a strategic weapon instead of a tactical function. The importance of timely, reliably, and adequate information

in the development and implementation of TQM has also been noted by researchers (Garvin 1983; Babbar 1992).

ERM also requires extensive information collection and analysis and the latest technology for managing information resources (Bracken 1985). Information technology can help reinforce the implementation of ERM practices (Johannson 1993). Many firm's have discussed several applications that directly relate to ERM (e.g., NASA, Geomatics International). By applying the tools of information planning to ERM, a company's information infrastructure can be aligned with strategic goals and business processes (Orlin, Swalwell, and Fitzgerald 1993). The challenges facing ERM companies is that environmental data usually resides in parallel information systems apart from other corporate data (Fitzgerald 1994). A key objective of information systems which support ERM is to integrate environmental information with core corporate processes. In the area of ERM, there is an enormous list of information needs, including both basic and more externally oriented questions. Therefore, a company needs to take a broad systems-type approach, similar to what is required with TQM, before it is satisfied that it has identified all it information needs (CGLI 1996). Information needs pertinent to ERM might include: 1) Who are your customers and stakeholders, and what are their expectations?; 2) What are the most important regulatory drivers?; 3) What are the true (full) costs, risks, and benefits associated with current or proposed approaches?; and 4) What are the major concerns expressed by customers, workers, neighbors, the public, and advocacy groups?

2.8.5 Human Resource Development

TQM demands that all aspects of human resource management (e.g., manpower planning, recruitment and staffing, training and development, performance appraisal, and rewards system management) assume strategic roles (Ahire, Landeros, and Golhar 1995). At the level of the individual, this should be reflected in qualified employees with an interest in doing quality work, satisfied with the training, development, appraisal, and reward system, and willing to offer their best to the TQM implementation process (Oliver 1988). At a group level, the performance of quality improvement teams, task forces, and quality circles becomes important (Cole 1980; Juran 1981a, 1981b). At a macro-level, an effective human resource management policy will result in an organizational culture of cooperation, consensus, and participation (Harber, Burgess, and Barchy 1993a; Longnecker and Scazzero 1993). Several articles identify training and development at all levels as the single best strategy to improve quality and productivity (Juran 1981a, 1981b; Ebrahimpour 1985; Lee and Ebrahimpour 1985).

The best results from ERM also can be only obtained when there is a high level of commitment and involvement from people (Wever and Vorhaur 1993). Many authors contend that using employee involvement teams for ERM is the most effective approach for most organizations (Cook and Seith 1991, 1992; Cramer and Roes 1993; May and Flannery 1995). The employees must recognize the environmental responsibilities both for the company and themselves. Training can shape employees' positive attitudes about their company's commitment to ERM (Marguglio 1991; Gupta and Sharma 1996). Given the limited resources of most state pollution prevention programs, using employee involvement teams

has made good sense (Enander and Pannullo 1990). By using this recourse, many state technical staffs created greater reductions in the generation of environmental waste in a shorter period of time. The most effective way to get employees involved is by linking the reward system to employee's efficiency and waste management. Gripman (1991) suggests 2 reward systems: 1) a system in which an employee's raise is determined, in part, by what the employee is doing in the area of waste reduction; and 2) a system in which an employee is honored at the end of the year for waste reduction ideas. Based on 8 detailed case studies of Dutch companies, Cramer and Roes (1993) show that employee involvement can be promoted by improving employee-management interaction and promoting responsibility for the environment among all levels of management including individual employees. A team orientation that uses the knowledge of employees to develop solutions for waste problems is a relevant TQM principle that can be integrated into ERM. Using such a team orientation for ERM has been advocated by a number of groups, most notably GEMI and the Council on Environmental Quality.

2.8.6 Process Management

The management of process quality examines how key processes are designed, effectively managed, and improved to achieve higher performance. The quality assurance and improvement efforts of an organization must not only include manufacturing, but also supporting functions which impact operations such as marketing, purchasing, and human resource management. In terms of an organization's quality assurance activities during the various production phases, researchers have primarily focused on the preproduction (product and process design and development) stages (Garvin 1984; Juran and Gryna 1988; Taguchi

and Clausing 1990; Stein 1991). These studies conclude that quality is an outcome of good design and it is only after developing a robust design that attention should be given to manufacturing. The literature is replete with discussions on various quality-control improvement techniques used to limit the number of allowable failures (Bhote 1989; Modaress and Ansari 1989; Benton 1991). These studies assess the use of various nonstatistical tools (cause and effect diagrams and checklists) and statistical techniques (scatter diagrams, frequency histograms, control charts, and sampling inspection plans). They concluded that the potential of these techniques in all areas of business had not been adequately exploited. The traditional approach of quality management prior to the 1980s in the U.S. was reactive, in which quality was inspected into the product and considered a tactical rather than strategic issue (Hayes 1981; Schonberger 1983; Garvin 1986). The Japanese on the other hand, viewed quality management as a long-term strategy, implemented, and monitored by top management.

ERM also begins during initial product and process design. The goals of ERM can only be achieved when environmental issues and concerns are identified and resolved during the early stages of product and process design, when changes can be made to reduce or eliminate environmental waste (Melnyk, Handfield, Calantone, and Curkovic 1997). Because a product and its manufacturing process need to be designed before a product is manufactured, the environmental effects of the product are largely fixed at the product process design phases (Van Weenen and Eeckles 1989). The concept of no allowable failure in TQM is readily applicable to ERM (Klassen and McLaughlin 1993). The same tools used for the foundation of TQM can be used to indicate potential avenues

of waste reduction (Wever and Vorhauer 1993). GEMI (1996) recommends that quality-based tools such as Pareto analysis, root-cause analysis, and continuous improvement be used to identify and prioritize ERM issues, identify alternative approaches, construct practicable plans, and allocate scarce resources. For ERM, statistical tools are particularly appropriate for eliminating errors in sampling and monitoring procedures (Blacker and Fratoni 1990). Data-driven tools which are relevant to TQM principles can be integrated into ERM (May and Flannery 1995). These data-driven tools include cause-and-effect diagrams, Pareto charts, and control charts to signal problems with the manufacturing process. Using such data-driven tools for ERM has been advocated by GEMI and the Council on Environmental Quality. Similar to the proactive approaches used by the Japanese in quality management, a prevention mindset is perhaps the most important element in the entire category of process management (CGLI 1994). Klassen and McLaughlin (1993) bring to attention that the gradual evolution of the "quality of life" and the environment has already been anticipated by Japanese authors. Mizuno (1988) favors active quality management that anticipates and works within the constraints of the system without missing any of the customer requirements. The system constraints that he proposes includes environmental pollution. He supports the position that ERM must move from a defensive to a more proactive posture.

2.8.7 Results

TQM requires that companies monitor and improve their quality performance based on objective measures of quality and operational results. Assuring customer-driven quality requires measurement of quality results. Researchers have suggested that world-class quality

performance is the result of understanding the factors that determine quality and product performance (Reddy and Berger 1983; Fortuin 1988). Other studies have concluded that firms need to focus on improving quality of every work process as measured by the needs of internal and external customers (Cole 1990; Fisher 1992).

Whenever ERM is implemented, measures should be identified to determine if the system is delivering the desired results (GEMI 1996). ERM results are defined as the organization's improvements in ERM (McGee and Bhushman 1993; CGLI 1994). Effective measurement in ERM begins with customer requirements and monitors performance in terms relevant to internal and external customers. ERM systems are no less dependent on measurement than TQM systems (Wells, Hochman, Hochman, and O'Connel 1994). According to Wells, Hochman, and O'Connel (1994), ERM requires that organizations monitor and improve their performance based on objective measures. Xerox Corporation, a former MBNQA winner, is a recognized leader in customer-driven environmental measurement. Xerox has devoted several years to building the perceived requirements of internal and external customers into its ERM system. The Global Environmental Management Initiative (1996) suggests that monitoring performance is integral to ERM; meaning, measures should be identified to determine if the system is delivering the desired results.

2.9 An Operational Framework of ERM

In Section 2.4, using the traits associated with TQM, and comparing these traits to the various constructs found in the literature, the MBNQA framework was determined to best fit the definition of TQM. Since the MBNQA framework was the most consistent definition of TQM, it will be used as the operational framework of TQM

(for the purposes of this dissertation research). An adaptation of the MBNQA framework will be used as the operational framework of ERM. Parallels were drawn between TQM and ERM to show that the two concepts are so closely linked, that any operational framework of TQM could be adapted for ERM.

CHAPTER 3

PRE-RESEARCH AND RESEARCH DESIGN

3.1 Introduction

There has been a great deal of discussion within the literature about TQM in environmental programs. ERM appears to be an area with strong potential for the development of process improvements; however, it has largely been ignored by operations practitioners and academics to date. Furthermore, many organizations, some of which tout the TQM philosophy, fail miserably as indicated by noncompliance (Augenstein 1995). The normative literature and case studies which predominates the ERM field suggests, but does not explicitly recognize, that in TQM there is an explainable, understandable, and documental path to ERM. Such postulated associations between TQM and ERM are mostly based on deductive reasoning and case analysis. Unfortunately, while case studies and deductive arguments have emphasized the virtues of TQM's role in ERM, researchers have not supported these arguments with extensive systematic empirical analyses. As was presented in Chapter 1, the overarching goal of this dissertation is to investigate the theoretical linkage between TQM and ERM via a structural equation model by answering the following research questions: 1) Is there a relationship between TQM and ERM systems?; and 2) If there is a relationship present between TQM and ERM, then what is the nature of the relationship?

The relationship between TQM and ERM is being examined while ERM theory is far from being fully developed (Post and Altman 1992; Klassen 1995). As was presented in Chapter 2, the ERM literature suffers from a lack of: 1) systematic scale development; 2) content validity; and 3)

empirical validation. In Section 2.8, parallels were drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM can be adapted for ERM. Therefore, an adaptation of the operational framework for TQM is used as the framework for ERM. For example, ERM is operationalized using four multi-item scales corresponding to an adaptation of the four categories associated with the operational framework for TQM (see Section 3.5). The expected scholarly contribution of this dissertation, in addition to investigating the theoretical linkage between TQM and ERM and the nature of this relationship, is to help build ERM theory by answering the following ancillary research question: 1) Are the TQM constructs good predictors for the ERM constructs?

ERM theory building will require a more forward and comprehensive outlook in which the theoretical constructs of ERM are developed. Furthermore, the advancement of the ERM field depends on giving priority to measurement. This is because theory construction and cumulative tradition, the ultimate objectives of any field, are inseparable from measurement (Bagozzi 1982). Thus, in order to move from anecdotes and case studies to testable models and hypotheses, it is critical to link theoretical concepts such as ERM to empirical indicants. In search for substantive relationships, the ERM field has overlooked the methodological issues such as measurement. This dissertation will contribute to ERM theory building by identifying the constructs associated with ERM, developing scales for measuring these constructs, and empirically validating the scales.

The structural equation model to be tested is shown in Figure 1.1. The model is defined in terms of first order factors which will be

measured by a set of observable indicator variables. The second order factors of TQM and ERM are each represented and defined by their four underlying first order factors. All paths are expected to have positive signs. The justification for these paths (i.e., βs and γ) and the specific research hypotheses depicted in the structural equation model are now examined in detail. The remaining portion of the chapter describes the research design and methodology used to test the structural equation model.

3.2 Specific Research Hypotheses

In Section 2.4, using the traits associated with TQM, and comparing these traits to the various constructs found in the literature, the Malcolm Baldrige National Quality Award (MBNQA) framework was determined to best fit the definition of TQM. Since the MBNQA framework was the most consistent definition of TQM, it is used as the operational framework of TQM for the purposes of this dissertation. For example, TQM will be operationalized using four multi-item scales which correspond to the three subsystems and the results category associated with the MBNQA framework. The 1997 MBNQA framework is described as three related subsystems (Evans 1997): 1) the "strategic" categories of leadership (1.0), strategic planning (2.0), and customer/market focus (3.0); 2) the "operational" categories of human resource development (5.0) and process management (6.0) (which lead to "results" (7.0)); and 3) the "information" category (4.0) that serves as the foundation for the other two subsystems. See Table 2.5 in Section 2.3.3.2 for definitions of each of the seven categories associated with the MBNQA.

In light of this discussion, it is hypothesized that the presence of TQM Strategic Systems, TQM Operational Systems, TQM Information Systems, and TQM Results encourages the emergence and acceptance of TQM; thus, β_1, β_2, β_3, and β_4 are proposed to be positive. More specifically:

Hypothesis 1 (H1): $\beta_1 > 0$, $p < 0.05$
Hypothesis 2 (H2): $\beta_2 > 0$, $p < 0.05$
Hypothesis 3 (H3): $\beta_3 > 0$, $p < 0.05$
Hypothesis 4 (H4): $\beta_4 > 0$, $p < 0.05$

In Section 2.8, parallels were also drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM can be adapted for ERM; therefore, an adaptation of the MBNQA is used as the operational framework of ERM. For example, ERM is operationalized using four multi-item scales corresponding to an adaptation of the four categories associated with the MBNQA framework. Thus, it is proposed that the presence of ERM Strategic Systems, ERM Operational Systems, ERM Information Systems, and ERM Results encourages the emergence and acceptance of ERM. The justification for these proposed relationships is now examined in greater detail.

An ERM Strategic System includes issues pertaining to *leadership*, *strategic planning*, and *customer/stakeholder focus*. More specifically, an ERM Strategic System collectively examines: 1) how senior leaders guide the company in setting directions and in developing and sustaining ERM values; 2) how the company sets strategic directions and how it determines key action plans for ERM issues; and 3) how the company determines the environmental requirements and expectations of customers and stakeholders. *Leadership*, *strategic planning*, and *customer/stakeholder focus* are now defined in the context of ERM Strategic Systems.

Leadership is defined as senior management's ability to create ERM values and in building these values into the way the organization operates. Leadership defines an organization's goals, expresses its commitment to protecting the environment, and provides the foundation on which ERM is developed. A common theme within the literature is the importance of leadership in creating a culture for ERM in which the concept that waste and pollution are inevitable is purged (Bemowski 1991). Research suggests, but does not explicitly recognize, that the critical guide and motivator for ERM must come from senior management leadership (Arthur D. Little, Inc. 1989; Hunt and Auster 1990; Schot 1991; Makower 1993, 1994; McGee and Bhushman 1993; Wever and Vorhaur 1993; Council of Great Lakes Industries 1994; Epstein 1996).

Strategic planning is defined as the effectiveness of an organization's integration of customer/stakeholder environmental requirements into its business plans. Customers and stakeholders can be external (i.e., consumers, regulators, legislators, suppliers, community and environmental groups) or internal (such as other departments within the company, higher management levels, shareholders, employees) (Global Environmental Management Initiative 1993). A strategic planning process for ERM is required to ensure that: 1) ERM will become an integral part of planning; and 2) a process will be in place to communicate with customers and stakeholders and include their input in planning (Wever and Vorhauer 1993). Researchers suggest, but do not explicitly recognize, that ERM must become a part of the organization's business plan with regular performance reviews to track progress (Hunt and Auster 1990; Epstein 1996). A business plan is defined as a document that details the methodology, strategy, funding, etc., used to attain

business goals (Council of Great Lakes Industries 1994). This document normally covers at least five fiscal years, and more often, the life of a product or project.

Customer/stakeholder focus is defined as the effectiveness of the organization's systems in determining customer/stakeholder requirements. ERM requires the adoption of response systems to handle the most basic of customer/stakeholder concerns or requirements (McGee and Bhushman 1993; Council of Great Lakes Industries 1994). Greater responsiveness to customer/stakeholder expectations should improve environmental performance of products, processes, and/or services (Global Environmental Management Initiative 1994). This factor requires the organization to foster openness and dialogue with customers/stakeholders, anticipating and responding to their concerns about the potential hazards and impacts of operations, products, and/or services (Clarkson 1991).

In light of this discussion pertaining to ERM Strategic Systems (leadership, strategic planning, and customer/stakeholder focus), it is proposed that the presence of ERM Strategic Systems encourages the emergence and acceptance of ERM, as is shown by β_5 in Figure 1.1. More specifically:

Hypothesis 5 (H5): $\beta_5 > 0$, $p < 0.05$

An ERM Operational System includes issues pertaining to *human resource development* and *process management*. More specifically, an ERM Operational System examines: 1) how the work force is enabled to develop and utilize its full potential, aligned with the company's ERM objectives; and 2) how key processes are designed, effectively managed,

and improved to achieve higher ERM performance. *Human resource development* and *process management* are now defined in the context of ERM Operational Systems.

Human resource development is defined as the success of an organization's efforts to realize the full potential of its workforce in implementing ERM. Human resource development examines the extent to which employees are educated, trained, and motivated to conduct their activities in an environmentally responsible manner. This factor also examines the extent to which education, training, and career development plans for employees have been linked to the organization's environmental goals. Many authors contend that ERM can only be achieved when there is a high level of commitment and involvement from people (Cook and Seith 1991, 1992; Gripman 1991; Marguglio 1991; Cramer and Roes 1993; Wever and Vorhaur 1993; May and Flannery 1995; Gupta and Sharma 1996).

Process management is defined as the effectiveness of the organization's systems for assuring ERM, with emphasis on continuous improvement and prevention. Several researchers have suggested that the environmental effects of products are largely fixed at the product and process design phases (Weenen and Eeckles 1989; Klassen and McLaughlin 1993). According to Melnyk et al. (1996), ERM can only be achieved when environmental issues and concerns are identified and resolved during the early stages of product and process design.

In light of this discussion pertaining to ERM Operational Systems (human resource development and process management), it is proposed that the presence of ERM Operational Systems encourages the emergence and acceptance of ERM, as is shown by β_6 in Figure 1.1. More specifically:

Hypothesis 6 (H6): $\beta_6 > 0$, $p < 0.05$

An ERM Information System is defined as the effectiveness of an organization's collection, analysis, and use of information for environmental planning and improvement. Bracken (1985) suggests that formalized ERM programs require extensive information collection and analysis. Johannson (1993) adds that information and analysis can reinforce the implementation of ERM practices. Orlin, Swalwell, and Fitzgerald (1993) show through a series of case studies that by applying the tools of information planning to ERM, an organization's information infrastructure can be aligned with business processes. The importance of timely, reliable, and adequate information in ERM has been noted by several researchers; however, it has not been explicitly recognized.

In light of this discussion pertaining to ERM Information Systems, it is proposed that the presence of ERM Information Systems encourages the emergence and acceptance of ERM, as is shown by β_7 in Figure 1.1. More specifically:

Hypothesis 7 (H7): $\beta_7 > 0$, $p < 0.05$

ERM Results are defined as the organization's improvements in ERM (McGee and Bhushman 1993; Council of Great Lakes Industries 1994). According to Wells, Hochman, and O'Connel (1994), ERM requires that organizations monitor and improve their environmental performance based on objective measures. The Global Environmental Management Initiative (1996) suggests that monitoring performance is integral to ERM; meaning, measures should be identified to determine if the system is delivering the desired results. In light of this discussion pertaining to ERM Results, it is proposed that the presence of ERM Results

encourages the emergence and acceptance of ERM, as is shown by β_8 in Figure 1.1. More specifically:

Hypothesis 8 (H8): $\beta_8 > 0$, $p < 0.05$

There has been a great deal of discussion within the literature about TQM in environmental programs. What is being argued is that TQM systems condition firms to be more interested in the need for an ERM system. When a TQM system precedes ERM, it is postulated to increase the probability of an ERM system being present. The systematic view of TQM, encompassing both the finished product or service and all the supporting activities to provide them, provides a strong rational for an explicit focus on ERM.

The normative literature and case studies which predominated the ERM field suggests, but does not explicitly recognize, that in TQM there is an explainable, understandable, and documental path to ERM. Such postulated associations between TQM and ERM are mostly based on deductive reasoning and case analysis. Unfortunately, while case studies and deductive arguments have emphasized the virtues of TQM's role in ERM, researchers have not supported these arguments with extensive systematic empirical analyses. Research directed at developing a rationally consistent theory of ERM which can be consistently related to TQM represents an unexplored proposition. In light of this discussion, it is hypothesized that the presence of a TQM based system encourages the emergence and acceptance of an ERM based system, as is shown by γ_1 in Figure 1.1. More specifically:

Hypothesis 9 (H9): $\gamma_1 > 0$, $p < 0.05$

ERM systems are viewed as being TQM systems modified to deal with environmental issues. The gradual evolution of quality to include aspects of the environment has been anticipated by several authors (Mizuno 1988; May and Flannery 1995; Sarkis and Rasheed 1995; Epstein 1996). The "no waste" aim of ERM based systems closely parallels the TQM goal of "zero defects." TQM focuses on waste as it applies to process inefficiencies, whereas ERM tends to focus more on concrete outputs, such as solid and hazardous waste. Because the two concepts share a similar focus, it makes sense to use many of the tools, methods, and practices of TQM in implementing an ERM based system. Given this perspective, the structure of ERM systems is expected to parallel or be very similar to that found in TQM systems. There is no reason, a priori, to believe that the structures associated with TQM and ERM based systems are different; therefore, the structures between TQM and ERM based systems are hypothesized to be similar or parallel one another. More specifically:

Hypothesis 10 (H10): $\beta_1 - \beta_5 = 0$, $p < 0.05$
Hypothesis 11 (H11): $\beta_2 - \beta_6 = 0$, $p < 0.05$
Hypothesis 12 (H12): $\beta_3 - \beta_7 = 0$, $p < 0.05$
Hypothesis 13 (H13): $\beta_4 - \beta_8 = 0$, $p < 0.05$

3.3 Measures to be Used for the TQM Measurement Model

In Section 2.4, using the traits associated with TQM, and comparing these traits to the various constructs found in the literature, the MBNQA framework was determined to best fit the definition of TQM. Since the MBNQA framework was the most consistent definition of TQM, it will be used as the operational framework of TQM.

The TQM measurement model will be operationalized using a set of four multi-item scales corresponding to the four basic factors of the

MBNQA framework: 1) TQM Strategic Systems which includes the leadership (1.0), strategic planning (2.0), and customer/market focus (3.0) categories; 2) TQM Operational Systems which includes the human resource development (5.0) and process management (6.0) categories; 3) TQM Information Systems which includes the information and analysis category (4.0); and 4) TQM Results (7.0). See Table 2.5 in Section 2.3.3.2 for definitions of each of the seven categories associated with the MBNQA.

The TQM measurement model will be operationalized using a set of multi-item scales already developed by Handfield and Ghosh (1997). The items were constructed based on descriptions provided in the MBNQA criteria and through confirmatory factor analysis (using loadings > 0.50 as a minimum value for inclusion of an item in an index) and reliability analyses (item to total correlations and Cronbach's alpha). The measures were also pretested through a set of interviews with managers in 14 North American and European manufacturing organizations in order to improve the clarity and content of each measure. The items for each factor are summarized below in Sections 3.3.1-3.3.4, with the corresponding dimensions of the MBNQA criteria addressed by each measure shown in the parentheses.

The focus of the measures is on real decisions made by plant managers (see Section 3.5.4) and the ultimate effects of those decisions, as viewed by them, irrespective of the theoretical correctness or incorrectness of those decisions. Consequently, all data will be based on managers' perceptions. While one could argue that focusing on managerial perceptions may miss the truth, this approach provides a balance by focusing on the real world approach of making

decisions on educated perceptions. The following sections list the factors and the scales used in the study.

3.3.1 Factor 1 (F1): TQM Strategic Systems

The TQM Strategic Systems factor includes and examines: senior executives' personal leadership and involvement in creating and sustaining a customer focus and clear and visible quality values; how the values and expectations are integrated into the company's management system; the company's planning process and how all key quality requirements are integrated into overall business planning; the company's short- and long- term plans and how quality and performance requirements are deployed to all work units; how the company determines requirements and expectations of customers and markets; and how the company enhances relationships with customers and determines their satisfaction (MBQNA 1997).

The TQM Strategic Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V1 - Quality goals are clearly communicated to all plant personnel (1.1).

V2 - Quality is emphasized through a well-defined set of quality policies and procedures within your plant (1.1).

V3 - Customer quality requirements are used to establish a plant level quality strategy (2.1).

V4 - Adequate resources are provided to carry out quality improvements within your plant (2.2).

V5 - Plant and/or other company personnel actively interacts with customers to set reliability, responsiveness, and other standards for the plant (3.1).

V6 - Key factors for building and maintaining customer relationships are identified and used by your plant (3.1).

V7 - Formal and informal customer complaints are evaluated by your plant (3.2).

3.3.2 Factor 2 (F2): TQM Operational Systems

The TQM Operational Systems factor includes and examines: how the work force is enabled to develop and utilize its full potential, aligned with the company's objectives; the company's efforts to build and maintain an environment conducive to full participation, and personal and organizational growth; the key aspects of process management, including customer-focused design, product and service delivery processes, support services and supply management involving all work units, including research and development; and how key processes are designed, effectively managed, and improved to achieve higher performance (MBQNA 1997).

The TQM Operational Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V8 - Human resources management within your plant is affected by quality plans (5.1).

V9 - An adequate amount of training in quality awareness is provided to hourly/direct labor employees within your plant (5.2).

V10 - An adequate amount of training in quality awareness is provided to managers and supervisors within your plant (5.2).

V11 - The work environment within your plant is conducive to employee well-being and growth (5.3).

V12 - The manufacturability of products built within your plant is considered during the product design process (6.1).

V13 - Easy access for customers seeking information or assistance and/or comment and complain is provided (6.2).

V14 - Suppliers' facilities are visited regularly by plant and/or other company personnel (6.3).

3.3.3 Factor 3 (F3): TQM Information Systems

The TQM Information Systems factor includes and examines: the scope, validity, analysis, management, and use of data and information to drive quality excellence and improve competitive performance; and the adequacy of the company's data, information, and analysis system to support improvement of the company's customer focus, products, services, and internal operations (MBNQA 1997).

The TQM Information Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V15 - Quality data within the plant is made visible - displayed at work stations (4.1).

V16 - Quality data within the plant is provided in a timely manner (4.1).

V17 - Quality data is made available to all employees within your plant (4.1).

V18 - Benchmark data is used to improve quality practices within your plant (4.2).

V19 - Procedures have been developed for monitoring key indicators of plant performance (4.2).

V20 - Procedures have been developed for monitoring key indicators of customer satisfaction (4.3).

3.3.4 Factor 4 (F4): TQM Results

The TQM Results factor includes and examines: the company's performance and improvement in key business areas - product and service quality, productivity and operational effectiveness, and supply quality (MBNQA 1997).

The questions for the TQM Results factor will be introduced by: "Please estimate the magnitude of change experienced in each quality measure over the last three years:" These measures will then be

converted into an 11-point bipolar scale ranging from 0 to 10, where "0"= +100% or >, "1"= +80%, "2"= +60%, "3"= +40%, "4"= +20%, "5"= no change, "6"= -20%, "7"= -40%, "8"= -60%, "9"= -80%, "10"= -100% or >.

V21 - After-sales customer complaints (7.1).

V22 - Customer rejection of our products (e.g., manufacturing defects) (7.1).

V23 - Defect rates/cost (7.2).

V24 - Employee absenteeism (7.3).

V25 - Cost of quality (e.g., inspection and testing) (7.2).

V26 - Employee grievances (7.3).

V27 - Employee turnover (7.3).

V28 - On-time delivery of purchased parts (7.4)(reversed scale).

V29 - Total cost of purchased parts (7.4).

3.4 Measures to be Used for the ERM Measurement Model

In Section 2.8, parallels were drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM could be adapted for ERM; therefore, the ERM construct will be conceptualized in terms of the four first order factors described by the MBNQA framework. Multi-item scales for each factor will serve as parsimonious representations of unidimensional constructs, corresponding in similarity to each of the four basic factors associated with the MBNQA framework.

The ERM literature in general suffers from a lack of systematic scale development. Therefore, the measures were pretested through a set of interviews with industry managers. The initial pretests were used to refine the survey instrument. Questions which were unclear or that

measured constructs other than those of interest were adjusted, reducing ambiguity and increasing reliability.

The following sections (3.4.1-3.4.4) deal with generating items that represent manifestations of the four first order factors associated with ERM. Definitions for these factors and the selection of items were developed from the MBNQA criteria, the literature, and items from other questionnaires. Each manifestation is measured with an item in a scale. The references are shown in parentheses following each measure.

3.4.1 Factor 5 (F5): ERM Strategic Systems

The ERM Strategic Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V30 - Environmental goals are clearly communicated to all plant personnel (Global Environmental Management Initiative 1994).

V31 - Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V32 - Employees throughout your plant are evaluated on environmental performance results (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V33 - Environmental requirements are used to establish a plant level environmental strategy (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V34 - Adequate resources are provided to carry out environmental improvements within your plant (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V35 - Processes have been developed to respond to customer/stakeholder (e.g., local community) questions and concerns regarding the environmental practices of your plant (Greening 1992).

V36 - Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

3.4.2 Factor 6 (F6): ERM Operational Systems

The ERM Operational Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V37 - Human resources management within your plant is affected by environmental plans (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V38 - An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V39 - An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant (McGee and Bhushman 1993; Council of Great Lakes Industries 1994).

V40 - Environmental issues are included in the product design process (Calantone, Handfield, and Melnyk 1997).

V41 - Environmental issues are included in the process design process (Calantone, Handfield, and Melnyk 1997).

V42 - Performance on environmental dimensions is considered during supplier evaluations by plant and/or other company personnel (Calantone, Handfield, and Melnyk 1997).

3.4.3 Factor 7 (F7): ERM Information Systems

The ERM Information Systems factor will be measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) with the following questions:

V43 - Environmentally-related information (e.g., changes in regulations) is used on an on-going basis by your plant (Calantone, Handfield, and Melnyk 1997).

V44 - Information about best-in-class environmental performance is tracked and recorded by your plant (Calantone, Handfield, and Melnyk 1997).

V45 - Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis (Calantone, Handfield, and Melnyk 1997).

V46 - Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications (Calantone, Handfield, and Melnyk 1997).

V47 - Cost accounting has been used extensively by your plant for capturing and reporting environmental problems and costs (Calantone, Handfield, and Melnyk 1997).

3.4.4 Factor 8 (F8): ERM Results

The questions for the ERM Results factor will be measured using an 11-point bipolar scale. Measures of ERM Results are required to ensure criterion validity. Criterion-related validity is a measure of how well the scales representing ERM are related to measures of ERM Results. To establish the criterion-related validity of the various ERM factors, the scale scores will be correlated with the primary outcome factor of ERM Results. Structural equation modeling will be used to estimate the correlations between the various factors and ERM Results.

The quantifiable measures for the ERM Results factor will be introduced by: "Please estimate the magnitude of change experienced in each environmental measure over the last three years:" These measures will then be converted into an 11-point bipolar scale ranging from 0 to 10, where "0"= +100% or >, "1"= +80%, "2"= +60%, "3"= +40%, "4"= +20%, "5"= no change, "6"= -20%, "7"= -40%, "8"= -60%, "9"= -80%, "10"= -100% or >.

V48 - Pre/post consumer recyclable content of direct materials (reversed scale).

V49 - Volume of wastewater discharges.

V50 - Tons of solid waste landfilled.

V51 - Volume of hazardous waste.

V52 - Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur oxides, etc.).

3.5 Research Design

3.5.1 Data Collection

The primary objective of this dissertation is to investigate the theoretical linkage between TQM and ERM via a structural equation model. In regards to examining ERM, case studies have been the predominant research methodology (Mahon 1983; Logsdon 1985; Miles 1987; Arthur D. Little 1989; Marguglio 1991; Schot 1991; Post and Altman 1992; Greenberg and Unger 1994; Shelton 1995). While normative literature and case studies have examined the underlying constructs associated with ERM, they have not been very well developed and suffer from a lack of empirical testing. One of the contributions of this dissertation will be to further develop and establish valid measures for the underlying constructs associated with ERM, which remain largely untested.

The importance of exploratory and situational ERM research should not be underscored. Case studies are very useful for building theories and getting to the heart of relationships (Eisenhardt 1989); however, the results of case studies are often difficult to generalize (Kerlinger 1986). Large scale empirical testing is useful because standardized measures, which are a necessity for making comparisons, can be used across a broad population in order to make generalizable conclusions (Fowler 1988). For the purposes of this dissertation, a survey will be used. The reason for this is that very few published empirical studies have undertaken broader scale investigations to empirically test hypotheses associated with ERM (Dillon & Fischer 1992; Klassen 1995). Empirical research in this direction will be required if ERM is to be transformed into a rationally and formally evaluated discipline. Currently, the ERM literature is titled heavily toward conceptual

analyses and anecdotal case examples of firms operating with superior environmental performance (Arthur D. Little, Inc. 1989; Hunt and Auster 1990; Dillon and Fischer 1992; Post and Altman 1992). However, as noted by Cairncross (1992) and Klassen (1995), anecdotal examples of ERM are often difficult to generalize between firms.

Investigating the theoretical linkage between TQM and ERM, as well as allowing for a deeper investigation of the underlying constructs, will be undertaken using a two-phase approach: 1) preliminary scale development will be conducted using interviews from managers; and 2) implementation of a large scale survey designed to validate scales for measuring the underlying constructs associated with TQM and ERM, and the nature of their relationship. This combination will allow for the exploitation of the strengths of both case studies and surveys while reducing the problems associated with both.

The primary objective of the first phase was to provide an indication of content validity, rather than build new theory as described by Eisenhardt (1989). Interviews with managers in six North American manufacturing facilities were used to provide assistance in the identification and prima facie validation of the constructs and variables in the dissertation. The scales had to be pretested for content validity before any refinement or validation was undertaken. A lack of content validity reflects items in a measurement instrument which do not properly measure the constructs they originally were purported to measure. Hence, any further analysis undertaken would become meaningless. Since items corresponding to the various constructs of the measurement instrument were derived from a comprehensive analysis of the literature, content validity was more adequately assured

(Bohrnstedt 1983). However, the research questionnaire was also validated for comprehensiveness and completeness in advance through interviews with industry managers. Each manager completed the questionnaire and provided feedback regarding the wording of items, their understandability, and the overall organization of the instrument. The measurement instrument was adjusted accordingly based on their feedback.

3.5.2 The Sample

Similar to much of the research in operations strategy, a single industry was chosen for the dissertation (Swamidass and Newell 1987; Vickery, Droge, and Markland 1993; Whybark and Vastag 1993; Ahire, Golhar, and Waller 1996). Focusing on a single industry controls for variance due to industry specific conditions. Industry differences may create significant differences in mean or modal responses. Industries may also differ in the consensus understanding of the meaning of terms. Controlling for industry effects can compensate for variability between industries, in terms of work force management, general market conditions, degree of unionization, etc. Controlling for these industry specific differences through the focus on one industry means that firm specific variance is highlighted in all subsequent analyses, and there is no variance due to industry specific conditions that can mask relationships of interest because of inflated error variance (Flynn et al. 1990).

This restriction permits the control of several variables that often differ between industries, including the scope and complexity of environmental concerns. However, for the industry selected, the types of environmental issues and range of ERM programs used must offer

sufficient variability for study; otherwise, it will not provide a strong basis for external generalizability. To empirically test a model dealing with TQM and ERM, an ideal industry would have three primary characteristics (Klassen 1995; Ahire, Golhar, and Waller 1996): 1) a high degree of variation in ERM programs; 2) in leader in the implementation of progressive quality management strategies; and 3) a competitive marketplace.

Klassen (1995) and Logsdon (1985) identified if an industry has been subjected to environmental regulation for many years, such as the steel, paper, chemical, pulp, or petroleum industries, then ERM becomes very standardized through contact with industry associations. At the other extreme, if regulation is nonexistent for an industry, then little variation in ERM is evident because there is often little perceived environmental impact. ERM is not crucial for all types of industries, and some managers will remain inherently skeptical about it (Shelton 1995). Thus, an ideal industry is one in which significant, new environmental regulation is under development or in its early stages of implementation (Logsden 1985; Klassen 1995; Shelton 1995). This state of uncertainty prompts some firms to try and lead the industry with new approaches, while many other firms adopt a "wait and see" approach; therefore, a high degree of variation in ERM is more likely. Based on these ERM criteria, the automotive industry was chosen; coincidentally, this industry has been used in earlier research on manufacturing strategy (Ahire, Golhar, and Waller 1996; Curkovic, Swartz, and Vickery 1997).

More specifically, the sample will be targeted across a 4-digit SIC code within the U.S. automotive industry: Motor Vehicle Parts &

Accessories (SIC 3714); establishments primarily engaged in manufacturing motor vehicle parts and accessories, but not engaged in manufacturing complete motor vehicles or passenger car bodies (i.e., air brakes, axle housings, brake drums, bumpers, camshafts, engines, exhaust systems, fuel pumps, manifolds, mufflers, etc.). A database of 2,945 manufacturing facilities from this SIC code was been obtained from Elm International, in East Lansing, MI. The list is the most comprehensive available and was updated within the three weeks of executing the research design.

The automotive industry meets all of the criteria discussed earlier. Historically, this industry has experienced much less regulation when compared to industries such as steel, chemicals, petroleum, paper, and pulp. At the time of the research, the major environmental issue facing the industry included the implementation of amendments to the Clean Air Act, along with other waste concerns. The primary forms of environmental waste within this industry are air emissions, pre/post consumer recyclability content of direct materials, and volumes of wastewater discharges, municipal solid waste, hazardous waste, and non-hazardous industrial waste.

Regulation is currently being introduced to control the air emissions of toxins such as Volatile Organic Compounds (VOCs) and Ozone Depleting Chemicals (ODCs). VOCs are chemicals commonly found in adhesives, paints, and cleaning solvents. These materials contribute to the "greenhouse effect" and are a cause of smog. ODCs such as Chloroflourocarbons (CFCs) and other solvent-based solutions contribute to the thinning of the stratospheric ozone layer. Possible options to reduce these emissions range from pollution control abatement equipment

(e.g., end-of-pipe technologies), to water based solutions, to improved equipment and techniques.

Individual plants within the industry are pursuing a variety of environmental strategies, and apparently with mixed results. Because of pending environmental requirements, such as those pertaining to amendments of the Clear Air Act, most plants are cognizant of the environmental issues, and a minority of firms are reportedly leading the industry in their attempts to improve performance in advance of the standards. However, many other firms have adopted a "wait and see" approach, indicating that a high degree of variability could be expected. There appears to be sufficient variation in environmental strategy, with both industry leaders and followers pursuing different strategies.

The automotive industry was also selected because it has been a leader in implementing progressive quality management strategies in the U.S. (Cole 1990). The industry has already been the focus many empirical studies which address quality management (Womack, Jones, and Roos 1990; Ahire, Golhar, and Waller 1996; Curkovic, Swartz, and Vickery 1997). Also, under the provisions of QS-9000, the Big 3 (General Motors, Ford, and Chrysler) are requiring that their own manufacturing facilities and those of suppliers upgrade their quality programs and methods. QS-9000 is a standard quality management system derived from ISO-9000 which has been developed for the Big 3 and its suppliers (Eastman 1995).

3.5.3 Unit of Analysis

The unit of analysis for empirical validation is an individual plant, rather than a Strategic Business Unit (SBU) or another subsidiary

level. The plant is the level of implementation for most quality management programs, and has been used in numerous other empirical studies related to quality (Schonberger 1983; Griffin 1988; Ebrahimpour and Withers 1992; Ahire, Golhar, and Waller 1996). Hence, the use of plants as the unit of analysis to examine TQM is strongly supported by previous research.

Many options about investment, other than those pertaining to quality management (e.g., environmental technologies), are also identified at the plant level, either by operating personnel, external consultants, or corporate specialists. As mentioned by Klassen (1995) through a series of case studies, an environmental investment portfolio is implemented at the plant level. The environmental investment portfolio was also shown to vary between plants even within the same firm, indicating that a more aggregated unit of analysis, such as the parent firm level, would likely obscure important differences.

It must be recognized that the development, integration, and growth of ERM in organizations will almost certainly be uneven within companies. Through a series of case studies, Shelton (1995) suggests that ERM should be organized as a plant level issue. ERM was shown not to be related to a large central organization or to uniform ERM organizations at the operating level. According to Shelton (1995), the more centralized ERM becomes, the more you will have to "put out fires," mediating disputes between central and operating units. Also, Klassen (1995), shows through a series of case studies that ERM can vary greatly between plants in the same industry. Environmental management varied between plants from "reactive" to "proactive," driven by differences in management and plant characteristics. However, it is reasonable to

assume that plants from within the same firm will be somewhat correlated in regards to ERM, and to minimize potential bias, the number of plants from any individual SBU would have to be limited in the final analysis.

3.5.4 Sample Selection

Research suggests that greater attention to informant selection can help to overcome the common method variance problem when practical considerations require single respondents (Miller and Roth 1994). Ideally, information should be gathered from multiple respondents at each site to minimize the potential for bias from a single respondent (Klassen 1995). However, the cost and time associated with obtaining access to individuals from large numbers of large sized plants in a specific SIC code would be beyond those available for this dissertation. Such a strategy was also not adopted because the response rate would likely be depressed to a critical level. Therefore, only single respondents (plant managers) were targeted for the dissertation. However, it is acknowledged that the use of multiple informants might enrich the data further and eliminate some of the biases and inaccuracies.

A high response rate from plant managers is the optimal outcome, but even a high response rate will not address several key issues associated with common method variance (Campbell and Fiske 1959) or the social desirability problem (Podsakoff and Organ 1986). Respondents might believe that there is an "ideal" response, and hence, give socially desirable answers that do not reflect actual practices. This problem cannot be mitigated with survey-based research and would actually require talking to people at the plant and actually seeing operations.

The survey mailout procedure will employ a three-step process similar to that recommended by Dillman (1978). Each survey will be mailed directly to the plant manager. Plant managers have been used as key respondents in empirical studies for both TQM (Schonberger 1983; Griffin 1988; Ahire, Golhar, and Waller 1996) and ERM (Klassen 1995). The first mailed research questionnaire will be accompanied by an explanatory letter, and then a reminder postcard will be sent to those plants not yet responding one week following the first mailout. Finally, two weeks after the original packet is mailed, another survey will be mailed out to the non-respondents.

3.6 Research Methodology

There will be two stages associated with the research methodology: 1) building the TQM and ERM measurement models; and 2) building the structural equation model. During the first stage of the research, the TQM and ERM measurement models will be tested using confirmatory factor analysis (CFA) before assessing the structural equation model shown in Figure 1.1. As noted by Fornell and Larker, "before testing for a significant relationship in the structural model, one must determine that the measurement model has a satisfactory level of validity and reliability" (1981: 45). Constructs must be unidimensional and reliable before assessing structural relationships among them (Anderson and Gerbing 1982).

A strong a priori basis for the hypothesized four factor models mandated the use of confirmatory factor analysis rather than exploratory factor analysis. This approach will use confirmatory factor analysis in various stages of scale refinement and validation. The approach is based on a two step procedure similar to that used in earlier scale

development for information technology and strategy (Venkatraman 1989; Sethi and King 1994). These steps are based on scale development research in marketing (Churchill 1979) and other social sciences (Bagozzi 1980). Klassen (1995) also used the two step procedure to validate the "Environmental Management Strategy" construct which was operationalized using three multi-item, seven-point scales corresponding to the three factors of planning/systems analysis, organizational structure, and management controls.

In the first step, each first order factor will be tested for internal reliability; otherwise, called unidimensionality (Klassen 1995). In the second step, an overall four factor confirmatory analysis will be performed using a latent variable measurement model for TQM and ERM each. The latent variable algorithm provides several statistics that can be used to assess the dimensionality of the first order factors and to estimate the reliabilities of the observed indicator variables in measuring the first order factors. The purpose is to ensure unidimensionality of the multiple-item constructs and to eliminate unreliable items from them. After eliminating items that load on multiple constructs or have low item-to-construct loadings, the Bentler-Bonett normed fit index (NFI), nonnormed fit index (NNFI), and comparative fit index (CFI) will be used to indicate if good fits of the CFA models to the data exist. Another reason why this multivariate technique is being used is because the first order factors associated with each measurement model are expected to be highly correlated. The latent variable methodology allows an analysis of both convergent and discriminant validity indicating whether related, but distinct factors are being measured with the multi-item scales.

Each of the two CFA models and overall structural equation model will be tested using the EQS for Windows software (Version 5.5) with covariance matrices as input. During the second stage of the research, a structural equation model will be formulated. The structural equation model describes the structural and measurement assumptions and consists of two parts: 1) the structural model; and 2) the TQM and ERM measurement models. Once the TQM and ERM measurement models have been empirically tested and validated from separate estimation (and respecification), the simultaneous estimation of the measurement and structural models will be conducted (yielding the complete model).

The test of the structural model constitutes a confirmatory assessment of nomological validity (Cronbach and Meehl 1955). The testing of the structural model, i.e., the testing of the initially specified theory which links TQM to ERM, will be meaningless unless it is first established that the TQM and ERM measurement models hold. Meaning, if the chosen indicators for the underlying constructs associated with TQM and ERM do not measure their constructs, the specified theory must be modified before it can be tested. Therefore, the TQM and ERM measurement models must be tested before the structural relationships linking these two concepts are tested. The resulting structural model can then be analyzed jointly with the two measurement models.

Under a structural equation modeling approach, a variety of unobservable variables can cause model specification errors (Hughes, Price, and Marrs 1986; Bollen 1989; Calantone, Schmidt, and Song 1996); therefore, there is concern for possible biases influencing the results. In other words, omitted variables may significantly bias the

results and interpretations (Boulding and Staelin 1990, 1995). Thus, there is a hidden threat to the validity of the results in this context. Tests which will be conducted to insure that specification errors are not biasing the results include: 1) a test of the theta delta matrix for each CFA model; and 2) an examination of nomological validity (Bagozzi and Yi 1989; Bollen 1989).

3.7 Limitations of the Research

The relationships between the second and first order factors will be empirically tested using a structural equation model. An advantage to this method is that the measurement properties of each factor can be tested simultaneously along with the structural relationships between constructs. This technique also allows correlations between variables to be controlled for, and allows for measurement error (Bollen 1989). However, a limitation to this methodology is that it can only serve to disconfirm a model, not prove it (Handfield and Ghosh 1997). In other words, the use of the structural equation model in Figure 1.1 is designed to only test whether the theoretical model can be rejected.

There are several other potential limitations to this research endeavor. In structural equation modeling, a large sample size is often required to maintain the accuracy of estimates. The need for larger sample sizes is also due in part to the program requirements and the multiple observed variables used to define the factors. Ding, Velicer, and Harlow (1955) indicated numerous studies that were in agreement that 100 to 150 subjects is the minimum satisfactory sample size when conducting structural equation models. Boosma (1982, 1983) recommend 400. The rule of thumb in statistics requires at least 5 responses minimum (10 responses ideal) per parameter, which for the purposes of

this dissertation would require a sample size of approximately 385 (77*5=385). Bentler and Chou (1987) suggested that a ratio as low as 5 subjects per parameter would be sufficient for normal distributions when the factors have multiple indicators. The target sample for data collection consists of 2,945 plants within the automotive industry. A 10-20% response rate would meet the sample size requirements which is a reasonable expectation for the purposes of this dissertation.

Using self report data from one source opens the data to contamination from correlations among variables. However, sometimes key informants provide the only avenue for information desired (Huber and Power 1985), and the practical utility of same source self-reports measures makes them virtually indispensable in many research contexts (Podsakoff and Organ 1986; Parkhe 1993). Phillips (1981) indicates that high ranking informants tend to be more reliable sources of information than their lower ranking counterparts; therefore, a high response rate from plant managers is an optimal outcome.

Although self-assessment measures are prone to potential bias, they are the most commonly used method in empirical research. A major advantage of using the perceived measurement scales is that it permits comparisons across plants, based on each individual manager's assessments within their own particular cultures, time horizons, economic conditions, and expectations. Consistent with the research design in this study, this scale captures the perceptions of the respondents that underlie their decisions, and it is easy and natural for respondents to use. Based on extensive pretests of the measurement instrument, the research was designed to limit the possibility of halo effects and socially desirable answers.

3.8 Validity Issues

Cook and Campbell (1979) identified four types of validity which all research should be judged on: 1) statistical conclusion validity; 2) construct validity; 3) internal validity; and 4) external validity. Statistical conclusion validity is a potential problem for this study if the power is not high. Cook and Campbell note that when the sample size is small it is dangerous to rely solely on statistical significance. However, with 2,945 plants being targeted for the research, and 77 parameters in the model, a 10-20% response rate would provide the statistical power required (77*5=385). Ahire, Golhar, and Waller (1996) obtained a 37% response rate using plants in the same SIC code.

Construct validity is a major problem with case studies, but the statistical procedures and design of this study should limit threats to construct validity. All of the TQM measures used will have been previously tested; however, this will not be the case for the ERM measures. The sample will also be large enough to perform confirmatory factor analysis to be sure that all the items load on the same underlying construct. In addition, the design of the study will combat threats to construct validity by the following: 1) having pre-specified relationships based on an exhaustive review of the literature; and 2) pretesting and refining all of the measures. This combination of strategies should mitigate some construct validity problems.

One might omit variables which significantly bias results and interpretation (Boulding and Staelin 1990, 1995). Thus, there is a hidden threat to the validity of the results in this context. An important criterion to be "not wrong" is whether an alternative explanation that firm level effects are operating as an invisible hand

can be defeated. There exists the possibility that the "omitted" firm variables bias the effect on performance and, indeed, even the intermediate effects in cross-sectional studies such as this. While the test of the theta delta matrix of each CFA measurement model may point to the lack of omitted variable bias, it has been attributed by some authors to the mere absence of a common method bias in measurement, and thus no definitive defense is available from that test alone. Thus, the challenge for a cross-sectional study such as this is to reject the hypothesis that many of the parameters associated with the dependent variables are biased by "omitted" firm level effects. Since only one observation was collected per plant in the sample, an examination of whether bias exists due to omitted firm effects is not possible.

Internal validity concerns deal with establishing causal relationships between variables. In nonrandomized designs, Cook and Campbell (1980) state that the researcher should explicitly rule out all possible threats. Many of the possible threats are not of concerns to this dissertation because the design is interested in only whether there is a strong correlation between the concepts of TQM and ERM. Therefore, problems such as history, maturation, instrumentation, and statistical regression to the mean should not be an issue.

While the directionality of the relationships was established theoretically, it is possible to argue that the directionality of the hypotheses could be reversed in some instances. For example, a causal relationship could be posed depicting TQM from ERM; however, there is no support in the literature for this relationship. The results would be grossly misleading because there is a conceptual flaw in the reversed relationship. The TQM-to-ERM link forms the proposed relationship for

the theoretical model. Ideally, one needs to collect time-series data to test causal relationships. While this dissertation will test if the model is consistent with the data, it will not be able to establish absolute causality.

The final validity issues pertains to external validity which is the ability to generalize the results beyond the present study. The major drawback of this single industry study is its lack of external validity. External validity is more easily achieved in cross-industry studies. However, a comparative profile of the plants across SIC code 3714 within the automotive industry highlights the diversity of the products manufactured. Plants in the sample would range from manufacturers of entire seating systems to manufacturers of anti-lock braking systems. Thus, the external validity of the results would not be severely compromised by a single industry study as it would if a more homogenous industry group was used. Hence, the findings of this study would have a much wider appeal than is typically associated with single-industry studies. Of course, external validity is never completely achieved through even a cross-industry study. External validity requires a series of different studies which substantiate and complement one another.

3.9 Reliability Issues

Practical considerations requires the use of single respondents for the purposes of this dissertation. This increases concerns regarding reliability issues; however, research suggests that greater attention to informant selection can help to overcome the common method variance problem (Miller and Roth 1994). Phillips (1981) indicates that high ranking informants tend to be more reliable sources of information

than their lower ranking counterparts. Initial pretests were used to refine the measurement instrument. Questions that were unclear or that measured constructs other than those of interest were changed or eliminated, reducing ambiguity and increasing reliability.

The methods addressed above will aid in increasing reliability; however, they are not measures of reliability and will not guarantee statistical conclusions. In order to ensure that the measures are reliable, reliability will be statistically analyzed using Cronbach's alpha.

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

Chapter 4 will use a two-stage process in which the TQM and ERM measurement models are first developed and validated, using confirmatory factor analysis (CFA), and then the measurement models are "fixed" in the second stage when the overall full structural equation model (SEM) is estimated. Because the structural portion of the overall SEM involves relations among only latent variables, and the primary concern in working with the overall SEM is to assess the extent to which these relations are valid, it is critical that the measurement of each latent variable is psychometrically sound. Thus, an important preliminary step in the analysis of such models is to first test the validity of the TQM and ERM measurement models before making any attempt to evaluate the overall SEM which examines the TQM-to-ERM linkage. Many researches are now proposing this two-stage approach (Kenny 1979; Williams and Hazer 1986; Anderson and Gerbing 1988). The rationale for this approach is that accurate representation of the reliability of the observed or manifest variables is best accomplished in two stages to avoid interaction of the measurement models and the overall SEM model (Hair et al. 1995).

The hypothesized overall model is portrayed in Figure 1.1 in terms of EQS notation. It represents a typical covariance structure model and can therefore be decomposed into submodels: 1) a TQM and ERM measurement model; and 2) an overall SEM. In Figure 1.1, there is a second-order TQM CFA measurement model. Likewise, there is also a second-order ERM CFA measurement model. These two second-order CFA

measurement models are linked to form an overall SEM. The SEM defines the pattern of relations among the unobserved factors and is identified by the presence of interrelated ellipses, each of which represents a construct or factor. The two measurement models are now reviewed in terms of EQS lexicon.

The EQS program command language syntax defines all variables as being in one of two different categories: observed (measured) variables, or unobserved (latent) variables. The measured variables have the prefix V, and the latent variables have the prefix F. Likewise, the measurement error associated with observed variables has the prefix E, and the measurement error associated with the prediction of a latent variable has the prefix D. All variables using EQS syntax are represented as either independent or dependent variables. Only for independent variables (latent or observed) can variances or covariances be estimated, and only for dependent variables can equations be entered. To set up any model, no matter how complicated, an equation is generated for each dependent variable. Then the main new concept needed to specify a model involves the variances of the independent variables, and possibly, their covariances or correlations.

The single-headed arrows leading from the second-order factor of TQM (F9) to each of its underlying first-order factors (F1,F9; F2,F9; F3,F9; F4,F9) are regression paths that indicate the prediction of TQM Strategic Systems (F1), TQM Operational Systems (F2), TQM Information Systems (F3), and TQM Results (F4) from a higher-order TQM factor. They represent second-order factor loadings. Likewise, the single-headed arrows leading from the second-order factor of ERM (F10) to each of its underlying first-order factors (F5,F10; F6,F10; F7,F10; F8,F10) are

regression paths that indicate the prediction of ERM Strategic Systems (F5), ERM Operational Systems (F6), ERM Information Systems (F7), and ERM Results (F8) from a higher-order ERM factor. They also represent second-order factor loadings. Finally, there is a residual disturbance term associated with each first-order factor (D1, D2, D3, D4 and D5, D6, D7, D8). These represent residual errors in the prediction of the first-order factors from the higher-order factors of TQM and ERM and are not shown in Figure 1.1. However, it is assumed that any variation occurring due to factors not included in Figure 1.1 is due to these disturbance terms.

The measurement models define relations between observed variables and unobserved constructs. In other words, they provide the link between item scores on the measurement instrument (see Appendix A) and the underlying factors they were designed to measure. The measurement models, then, specify the pattern by which each item loads onto a particular factor. These submodels can be identified by the presence of rectangles, each of which represents an observed or manifest variable. The single-headed arrows leading from each first-order factor to the rectangles are regression paths that link each of the factors to their respective set of observed variables. These coefficients (Vs,Fs) represent the first-order factor loadings. Finally, the single-headed arrow pointing to each rectangle represents observed measurement error associated with the observed variables.

Expressed more formally, the CFA models portrayed in Figure 1.1 hypothesizes a priori that: 1) TQM and ERM can be conceptualized in terms of four factors each; 2) each observed variable will have a nonzero loading on the factor it was designed to measure and zero

loadings for all other factors; 3) error terms associated with each observed variable will be uncorrelated; 4) the four first-order factors for each measurement model will be correlated; and 5) covariation among the four first-order factors for each measurement model will be explained fully by their regression onto the second-order factors.

One important omission in Figure 1.1 is the presence of double-headed arrows among the first-order factors thereby indicating their intercorrelation. This is because the development and validation of the TQM and ERM measurement models progresses from the first- to second-order factors which will indicate that all covariation among the first-order factors is explained by the second-order factors.

Furthermore, the development and validation of the measurement models will be conducted using responses from only the first wave of surveys received. Once the TQM and ERM measurement models have been developed and validated at the first- and second-order levels using responses from the first wave, a test for invariance across both the first and second waves of responses will be performed. This test will determine whether the factorial structures of the measurement models replicate across independent samples of the same population which addresses the issue of non-response bias, and more importantly, cross-validation. If the two waves are considered to be equivalent, then the data can be pooled and all subsequent investigative work will then be based on a single group analysis (Joreskog 1971). Meaning, a test of the overall SEM will be conducted using responses from both waves.

4.2 The Data

A two-wave mailing, with reminder postcards sent in between, employed many of the techniques developed by Dillman (1978), and

resulted in the return of 269 and 257 usable surveys from the first and second wave of responses, respectively. Responses from the first wave will be referred to as Group 1. Likewise, responses from the second wave will be referred to as Group 2. The sample was targeted across a 4-digit SIC code within the U.S. automotive industry: Motor Vehicle Parts & Accessories (SIC 3714). The unit of analysis was the individual plant. Only single respondents were targeted -- plant managers. See Section 3.5 for more detail regarding data collection, the sample, unit of analysis, and sample selection. Descriptive statistics of the survey respondents for Groups 1 and 2 are provided in Tables 4.1 and 4.2, respectively.

Table 4.1. Group 1 Respondents (n=269)

	Mean	Std. Dev.	Median	Min.	Max.
Respondent's Experience in Current Position (Years)[a]:	5.898	5.186	4	0.7	30
Number of Employees[b]:	309.344	297.800	221	15	1,975
Plant Size (Square Feet)[c]:	171,464.559	184,711.979	120,000	10,000	1,500,000
1995 Sales Volume ($)[d]:	53,997,726.25	66,497,170.36	35,000,000	1,000,000	640,000,000
1996 Sales Volume ($)[e]:	61,764,063.31	76,658,230.06	40,000,000	1,000,000	690,000,000
Average Age of Production Equipment (Years)[f]:	10.070	7.200	8	0.5	50

[a] n = 263, [b] n = 183, [c] n =177, [d] n = 232, [e] n = 232, [f] n = 266

* n varies because data elements were unavailable for some observations

Held Title of Plant Manager:	113
Held Other Title (e.g., V.P., President, C.E.O, G.M., etc.):	152
No responses to title:	4

Union Representation:	93
Non-Union Representation:	176

Number of Plants by Region: Michigan (67); Ohio (20); Illinois (10); Kentucky (10); Indiana (9); Tennessee (9); Virginia (7); Arkansas (6); North Carolina (5); Georgia (4); Missouri (4); Wisconsin (4); Connecticut (3); New York (3); Pennsylvania (3); Texas (3); California (2); Iowa (2); New Hampshire (2); Florida (1); Louisiana (1); Minnesota (1); Mississippi (1); Nebraska (1); Oklahoma (1); South Carolina (1); South Dakota (1)

Table 4.1. Group 1 Respondents (n=269) (continued)

Parent Firm**:	
Publicly Traded	110
Foreign-Owned Subsidiary/Transplant	35
Privately Owned	121
Joint Venture	10

** Note, more than one type of ownership might apply to a parent firm.

Table 4.2. Group 2 Respondents (n=257)

	Mean	Std. Dev.	Median	Min.	Max.
Respondent's Experience in Current Position (Years)[a]:	6.047	5.708	4	0.5	40
Number of Employees[b]:	362.725	456.281	235	24	3,500
Plant Size (Square Feet)[c]:	184,578.4	240,612.387	115,000	13,000	2,000,000
1995 Sales Volume ($)[d]:	60,511,771.69	101,559,088.4	30,000,000	1,000,000	1,076,593,000
1996 Sales Volume ($)[e]:	67,409,102.4	104,760,507.6	32,000,000	1,800,000	998,789,000
Average Age of Production Equipment (Years)[f]:	11.034	8.429	10	1	50

[a] n = 251, [b] n = 149, [c] n =145, [d] n = 219, [e] n = 223, [f] n = 249

* n varies because data elements were unavailable for some observations

Held Title of Plant Manager:	96
Held Other Title (e.g., V.P., President, C.E.O, G.M., etc.):	160
No Responses to Title:	1

Union Representation:	82
Non-Union Representation:	175

Number of Plants by Region: Michigan (36); Ohio (18); Illinois (17); Indiana (14); Tennessee (11); Kentucky (10); Pennsylvania (5); Virginia (5); Wisconsin (4); Georgia (3); Massachusetts (3); North Carolina (3); California (2); Florida (2); Iowa (2); Minnesota (2); Missouri (2); New York (2); Texas (2); Arkansas (1); Connecticut (1); New Hampshire (1); Oklahoma (1); South Carolina (1); South Dakota (1); Utah (1)

Parent Firm**:	
Publicly Traded	97
Foreign-Owned Subsidiary/Transplant	53
Privately Owned	121
Joint Venture	14

** Note, more than one type of ownership might apply to a parent firm.

4.3 Assessment of Measurement Model Fit

From a theoretical perspective, the measurement properties of a construct are assessed using a variety of criteria, e.g., internal and external validity (Loevinger 1967; Sethi and King 1994), theoretical meaningfulness, internal consistency of operationalization, convergent validity, discriminant validity, and nomological validity (Bagozzi 1980). From an operational perspective, however, the following minimal subset is considered important (Peter 1981; Venkatraman 1989; Klassen 1995): unidimensionality and convergent validity, discriminant validity, criterion-related validity, nomological validity, and reliability.

The measurement properties of TQM and ERM were first assessed by testing the initially hypothesized full first-order TQM and ERM measurement models using confirmatory factor analysis (CFA). A strong a priori basis for the hypothesized four factor TQM and ERM measurement models warranted the use of CFA rather than exploratory factor analysis. Based on theory, past research, and exploratory factor analyses, a CFA was performed since CFA is a more rigorous method for assessing unidimensionality rather than coefficient alpha, exploratory factor analysis, and item-total correlations (Gerbing and Anderson 1988; Calantone, Schmidt, and Song 1996). The purpose was to ensure unidimensionality of the multiple-item constructs and to eliminate unreliable items from them.

The four factors were combined into a structural equation model for CFA with explicit estimation of the correlation between factors. The model is given by:

$$\mathbf{x} = \Lambda\xi + \delta$$

where **x** is a vector of *q* observed variables (items from the survey instrument), ξ is a vector of *n* (*n* < *q*) unobservable variables called common factors (F1, F2, F3, F4 and F5, F6, F7, F8), δ is a vector of unique factors (unexplained variance or error terms) for the survey items, and Λ is a *q* by *n* matrix of unknown parameters called factor loadings. Under the standard assumptions (Joreskog and Sorbom 1978), the variance-covariance matrix of **x**(Σ) can be written as:

$$\Sigma_{xx} = \Lambda\phi\Lambda' + \psi$$

where ϕ is the matrix of inter-correlations among the four common factors and ψ is the covariance matrix of the unique factors. CFA usually assumes that the errors are uncorrelated, and ψ reduces to a diagonal matrix of error variances for the observed variables. Further, factor analysis assumes that the factors are uncorrelated, namely that ϕ equals the identity matrix (Dillon and Goldstein 1984). This last assumption was not expected to be appropriate for the four first-order factors. Theory proposed that they would be significantly correlated since they are predicted from the same higher-order factor.

The estimation of parameters in the model was determined using maximum likelihood (ML) estimation (Bollen 1989; Bentler 1992a; Joreskog and Sorbom 1993). Joreskog (1972) proposed an ML estimator (based on the multinormality of the observed variables) for general structural equation models. To date, the most widely used fitting function for structural equation models is the ML function (Bollen 1990). ML estimation chooses values of the parameters to reproduce the covariance matrix of observed variables using a fitting function.

The most widely used program is LISREL (Linear Structural RELations), a flexible model for a number of research situations (e.g., cross-sectional, experimental, and longitudinal studies). LISREL has found applications across all fields of study and has become synonymous with structural equation modeling. However, a number of alternative programs exist, among them EQS, which places less stringent assumptions on the multivariate normality of the data. The applications of structural equation modeling within this dissertation were executed using the EQS/Windows Version 5.5 program (Bentler 1989; 1992a). This program operates within the environment of Microsoft Windows and can perform many statistical, graphical, and data handling procedures that previously required the use of other statistical packages such as BMDP, SPSS, or SAS. Using EQS/Windows, you can prepare a raw data set, identify and impute missing values, visually inspect the data, identify and delete outliers, and plot and print graphs.

One of the more widely used statistics for overall fit is the χ^2 statistic. The probability level associated with the χ^2 statistic gives the probability of attaining a large χ^2 value given that the hypothesized model is supported. Values of $p \geq 0.10$ are usually indicative of a reasonable fit of the model to the data. A non-significant χ^2 statistic indicates that the covariance matrix of the proposed model does not differ significantly from the observed (sample) covariance matrix. However, given the known sensitivity of the statistic to sample size, use of the χ^2 index by itself provides little guidance in determining the extent to which the model does not fit (Bollen 1989; Chau 1997). Hartwick and Barki (1994) pointed out a

major shortcoming of this index. Namely, in large samples, the χ^2 statistic will almost always be significant, since χ^2 is a direct function of sample. The χ^2 measure is especially sensitive to sample size in cases where the sample size exceeds 200 respondents (Hair et al. 1996). As a result, a number of researchers (Wheaton, Muthen, Alvin, and Summers 1977; Byrne 1994; Hartwick and Barki 1994; Sethi and King 1994; Chau 1997) use a related measure, χ^2 divided by its degrees of freedom, which should be less than 3. A small value of χ^2 relative to the degrees of freedom signifies that the observed and estimated matrices do not differ considerably.

Various descriptive measures have been proposed that reduce or eliminate the sample size dependency. More practical indices of fit include the normed and nonnormed fit indices (NFI, NNFI; Bentler and Bonett 1980) and the comparative fit index (CFI; Bentler 1990a), a revised version of the NFI that overcomes the underestimation of fit in small sample sizes (i.e., given a correct model and small sample, the NFI may not reach 1; Bentler 1992a). Several other researchers support the use of these measures of overall model goodness of fit (Segars and Grover 1993; Hartwick and Barki 1994; Chau 1997). Although these three indices of fit are provided in the EQS output, Bentler (1992b) recommends the CFI to be the index of choice. Values for both the NFI and CFI range from 0 to 1 and are derived from the comparison of a hypothesized model with the independence model. Each provides a measure of complete covariation in the data, with a value greater than 0.90 indicating an acceptable fit to the data. The NNFI was originally designed to improve the NFI's performance near 1. However, because NNFI

values can extend beyond the 0-1 range, evaluation of fit is not as readily discernible as it is with the standardized indices. Many researchers recommend that multiple fit criteria be used (Breckler 1990; Bollen and Long 1993; Tanka 1993; Wheaton 1987).

4.3.1 Identification

In SEM, it is crucial that the identification issue be resolved prior to estimating the parameters. With identification, the following question is asked: On the basis of the sample data contained in the sample covariance matrix, *S*, and the theoretical model implied by the population covariance matrix, Σ, can a unique set of parameters be found? There are three levels of model identification. First, a model is said to be underidentified if one or more parameters may not be uniquely determined because there is not enough information in the matrix *S*. Second, a model is said to be just-identified if all of the parameters may be uniquely determined because there is just enough information in the matrix *S*. Third, a model is said to be overidentified when there is more than one way of estimating a parameter (or parameters) because there is more than enough information in the matrix *S*. If a model is either just- or overidentified, then the model is said to be identified. If a model is underidentified, the parameter estimates are not to be trusted (Schumacker and Lomax 1996).

As a first step in determining whether the first-order TQM and ERM CFA measurement models are identified, the number of parameters to be estimated are tallied up. In the first-order TQM CFA model, there are 29 factor loadings, 29 measurement error variances, and 6 factor covariances, making a total of 64 (see Figure 1.1). Given that there

are 29 observed measures in the model, there are 435 pieces of information in the sample-covariance matrix (29[29+1]/2=435). Therefore, this model is identified with 371 degrees of freedom.

Likewise, in the first-order ERM CFA model, there are 23 factor loadings, 23 measurement error variances, and 6 factor covariances, making a total of 52. Given that there are 23 observed variables in the model, there are 276 pieces of information in the sample-covariance matrix (23[23+1]/2=276). Therefore, this model is identified with 224 degrees of freedom.

4.3.2 Treatment of Nonnormality

One critical assumption of structural equation modeling is that the data are multivariately normal. The extent to which they are not bears on the validity of the findings. Although it is unlikely that the ML estimates would be affected, nonnormality could lead to downwardly biased standard errors that would result in an inflated number of statistically significant parameters (Muthen and Kaplan 1985; Byrne 1994). Violation of this assumption can seriously invalidate statistical hypothesis-testing such that the normal theory test statistic may not reflect an adequate evaluation of the model under study (Browne 1982, 1984; Hu, Bentler, and Kano 1992).

Since raw data were used as input, EQS automatically provides univariate as well as several multivariate sample statistics. The univariate statistics represent the mean, standard deviation, skewness, and kurtosis (see Tables 4.3 and 4.4). As expected, the items were not found to be severely kurtotic. Values for kurtosis ranged from -0.016 to 5.808 for TQM and -1.149 to 4.197 for ERM. No indications of

departures from normality existed (e.g., skewness ≥ 2, kurtosis ≥ 7; Chou and Bentler 1995).

Table 4.3. Univariate Statistics: Initially Hypothesized First-Order TQM CFA Model

Variable	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
Mean	8.732	8.833	8.773	7.829	8.249	7.851	9.372	7.517	7.201	7.911
Skewness	-1.188	-1.761	-1.647	-0.840	-1.362	-1.103	-2.065	-0.945	-0.555	-0.887
Kurtosis	1.206	3.451	3.479	-0.016	2.521	1.158	4.908	0.582	0.059	1.234
Std. Dev.	1.420	1.498	1.480	1.963	1.730	1.920	1.035	2.224	2.001	1.668
Variable	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**
Mean	8.048	7.855	8.502	6.981	7.762	8.123	8.364	6.625	8.963	8.394
Skewness	-1.343	-1.398	-1.093	-0.500	-1.123	-1.184	-1.798	-0.578	-2.116	-1.557
Kurtosis	2.408	2.126	1.287	-0.659	0.956	1.369	3.314	-0.148	5.808	2.941
Std. Dev.	1.750	2.108	1.450	2.365	2.272	1.866	2.137	2.473	1.491	1.835
Variable	**V21**	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**	
Mean	6.152	6.428	5.944	5.190	5.178	5.126	5.141	5.227	4.985	
Skewness	-0.768	-0.868	-0.594	-0.741	-0.144	-0.528	0.219	0.075	-0.914	
Kurtosis	0.251	0.275	0.598	2.877	1.546	3.814	2.632	0.660	3.869	
Std. Dev.	2.498	2.630	2.273	1.561	1.666	1.571	1.490	2.027	1.499	

Table 4.4. Univariate Statistics: Initially Hypothesized First-Order ERM CFA Model

Variable	**V30**	**V31**	**V32**	**V33**	**V34**	**V35**	**V36**	**V37**	**V38**	**V39**
Mean	5.264	6.011	3.149	6.030	6.379	5.926	4.141	5.450	5.691	6.126
Skewness	-0.066	-0.286	0.668	-0.487	-0.670	-0.442	0.268	-0.244	-0.399	-0.608
Kurtosis	-0.715	-0.814	-0.404	-0.991	-0.301	-0.812	-1.049	-1.040	-0.756	-0.532
Std. Dev.	2.628	2.742	2.740	3.137	2.685	3.012	3.072	3.098	2.831	2.748
Variable	**V40**	**V41**	**V42**	**V43**	**V44**	**V45**	**V46**	**V47**	**V48**	**V49**
Mean	5.494	6.283	4.539	6.483	3.112	3.234	4.089	3.851	4.967	5.413
Skewness	-0.298	-0.630	0.134	-0.578	0.763	0.688	0.295	0.425	-0.049	-0.117
Kurtosis	-0.981	-0.572	-0.928	-0.635	-0.462	-0.594	-1.149	-1.024	4.196	2.087
Std. Dev.	3.110	2.995	2.996	2.844	2.985	2.993	3.255	3.174	1.601	1.864
Variable	**V50**	**V51**	**V52**							
Mean	5.472	5.654	5.472							
Skewness	-0.208	-0.134	0.408							
Kurtosis	2.696	1.270	2.156							
Std. Dev.	1.679	2.067	1.811							

The multivariate statistics reported by EQS represents variants of Mardia's (1970) coefficients of multivariate kurtosis (see Tables 4.5 and 4.6). Two reported values bear on normal theory and two on elliptical theory. For TQM, the normalized estimate of Mardia's coefficient was 43.007, whereas for ERM, it was 38.078. Both values are distributed in very large samples from a multivariate normal population as a normal variate so that the small positive values, as shown in Tables 4.5 and 4.6, fail to indicate significance (Mardia 1970; Byrne 1994).

Table 4.5. Multivariate Kurtosis: First-Order TQM CFA Model

Mardia's Coefficient =	222.377
Normalized Estimate =	43.007
Elliptical Theory Kurtosis Estimates	
Mardia-Based Kappa =	0.247
Mean Scaled Univariate Kurtosis =	0.627
Mardia-Based Kappa is Used in Computation. Kappa =	0.247

Table 4.6. Multivariate Kurtosis: First-Order ERM CFA Model

Mardia's Coefficient =	157.464
Normalized Estimate =	38.078
Elliptical Theory Kurtosis Estimates	
Mardia-Based Kappa =	0.274
Mean Scaled Univariate Kurtosis =	-0.020
Mardia-Based Kappa is Used in Computation. Kappa =	0.274

EQS is unique in its ability to identify multivariate outliers. The program automatically prints out the five cases contributing most to Mardia's multivariate kurtosis coefficient. Identification of an outlier is based on the estimate presented for one case relative to those for the other four cases. There is no absolute value upon which

to make this judgment, and it is possible that none of the five cases is actually an outlier. To determine the effect of a single outlier, a simple initial procedure computed the sample covariance matrix with and without the outlier included. This provided some identification of the effect of the outlier on the input data. A simple follow-up procedure was a model analysis, both with and without the outlier included. A comparison of the results was then made to examine the outlier's impact. Since the results were comparable, none of the outliers were omitted for both the TQM and ERM measurement models.

4.3.3 Testing the Hypothesized Measurement Models

A summary of selected fit indices for the EQS analysis is provided in Tables 4.7 and 4.8. Results are reported for analyses that took the normality of the data into account based on normal theory estimation (i.e., data were considered to be normally distributed).

Table 4.7. Goodness-of-Fit Indices for the Initially Hypothesized First-Order TQM CFA Model

n	269 (Group 1: First Wave Responses)
Number of Latent Variables	4
Total Number of Observed Variables	29
Degrees of Freedom (df)	371
χ^2 Statistic	995.468
p-Value	0.001
χ^2 /df	2.68
Bentler-Bonett Normed Fit Index	0.747
Bentler-Bonett Nonnormed Fit Index	0.806
Comparative Fit Index	0.823

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	0.927215	1.000	5.07638
2	0.238896	1.000	3.86223
3	0.066529	1.000	3.77028
4	0.031745	1.000	3.73636
5	0.020597	1.000	3.72270

Table 4.7. Goodness-of-Fit Indices for the Initially Hypothesized First-Order TQM CFA Model (continued)

6	0.011956	1.000	3.71743
7	0.007162	1.000	3.71549
8	0.004167	1.000	3.71479
9	0.002432	1.000	3.71455
10	0.001406	1.000	3.71446
11	0.000815	1.000	3.71443

Table 4.8. Goodness-of-Fit Indices for the Initially Hypothesized First-Order ERM CFA Model

n	269 (Group 1: First Wave Responses)
Number of Latent Variables	4
Total Number of Observed Variables	23
Degrees of Freedom (df)	224
χ^2 Statistic	948.927
p-Value	0.001
χ^2 /df	4.24
Bentler-Bonett Normed Fit Index	0.773
Bentler-Bonett Nonnormed Fit Index	0.791
Comparative Fit Index	0.815

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	2.652018	1.000	6.58045
2	0.534851	1.000	3.75976
3	0.153569	1.000	3.60955
4	0.042828	1.000	3.58207
5	0.034244	1.000	3.56649
6	0.023715	1.000	3.55667
7	0.019474	1.000	3.55044
8	0.015040	1.000	3.54657
9	0.011916	1.000	3.54422
10	0.009253	1.000	3.54283
11	0.007188	1.000	3.54201
12	0.005555	1.000	3.54153
13	0.004304	1.000	3.54124
14	0.003344	1.000	3.54107
15	0.002615	1.000	3.54096
16	0.002058	1.000	3.54089
17	0.001632	1.000	3.54084
18	0.001303	1.000	3.54081
19	0.001048	1.000	3.54079
20	0.000847	1.000	3.54077

As point of interest, the iterative summaries for each CFA model were included in Tables 4.7 and 4.8. Shown is a synopsis of the number of iterations required for a convergent solution and the mean absolute change in parameter estimates (PARAMETER ABS CHANGE) associated with each iteration. The best scenario is a situation where only a few iterations are needed to reach convergence; after the first two or three iterations, the change in parameter estimates stabilizes and remains minimal. As is indicated in Tables 4.7 and 4.8, this is the case with the TQM and ERM CFA models, respectively. Eleven and 20 iterations were needed for a convergent solution for the TQM and ERM CFA models, respectively. The default start values did not seem to harm the first iterations for both models. However, convergence was very slow for both models in the middle iterations and beyond. The minimum function for both models did not appear to be well-defined.

Presented with findings of $\chi^2_{(371)} = 995.468$ and CFI = 0.823 for the first-order TQM CFA model, and $\chi^2_{(224)} = 948.927$ and CFI = 0.815 for the first-order ERM CFA model, further modification was needed to improve model fits to acceptable levels. The goodness-of-fit indices were much too low for well-fitting models. When a hypothesized model is tested and the fit found to be inadequate, it is customary to proceed with post-hoc model fitting to identify misspecified parameters in the model (Bollen 1989; Byrne 1994). Parameter estimates should have the right sign and size and small standard errors, as indicated by their t-values (Joreskog and Sorbom 1993; Sethi and King 1994). Tables 4.9 and 4.10 provide the measurement equations and standardized solution, respectively, for the initially hypothesized first-order TQM CFA model.

Likewise, Tables 4.11 and 4.12 provide the measurement equations and standardized solution, respectively, for the ERM CFA model.

Table 4.9. Measurement Equations With Standard Errors and Test Statistics (TQM)

	Measurement Equation	Standard Error	t-value
TQM Strategic Systems (F1):			
V1=	0.990*F1 + 1.000 E1	0.080	12.450
V2=	1.074*F1 + 1.000 E2	0.083	12.921
V3=	0.811*F1 + 1.000 E3	0.088	9.200
V4=	1.297*F1 + 1.000 E4	0.112	11.603
V5=	1.107*F1 + 1.000 E5	0.099	11.129
V6=	1.431*F1 + 1.000 E6	0.105	13.627
V7=	0.481*F1 + 1.000 E7	0.063	7.601
TQM Operational Systems (F2):			
V8=	1.220*F2 + 1.000 E8	0.132	9.267
V9=	1.677*F2 + 1.000 E9	0.103	16.255
V10=	1.403*F2 + 1.000 E10	0.086	16.350
V11=	1.049*F2 + 1.000 E11	0.102	10.315
V12=	0.693*F2 + 1.000 E12	0.132	5.241
V13=	0.676*F2 + 1.000 E13	0.088	7.679
V14=	1.034*F2 + 1.000 E14	0.145	7.138
TQM Information Systems (F3):			
V15=	1.741*F3 + 1.000 E15	0.123	14.143
V16=	1.515*F3 + 1.000 E16	0.099	15.381
V17=	1.520*F3 + 1.000 E17	0.119	12.757
V18=	1.610*F3 + 1.000 E18	0.142	11.357
V19=	0.824*F3 + 1.000 E19	0.089	9.276
V20=	1.066*F3 + 1.000 E20	0.108	9.845
TQM Results (F4):			
V21=	2.031*F4 + 1.000 E21	0.129	15.742
V22=	2.323*F4 + 1.000 E22	0.130	17.932
V23=	1.906*F4 + 1.000 E23	0.115	16.519
V24=	0.922*F4 + 1.000 E24	0.090	10.233
V25=	0.990*F4 + 1.000 E25	0.096	10.318
V26=	0.980*F4 + 1.000 E26	0.089	10.953
V27=	0.688*F4 + 1.000 E27	0.090	7.680
V28=	*-0.979**F4 + 1.000 E28	0.121	-8.080
V29=	0.874*F4 + 1.000 E29	0.087	10.080

* All factor loadings are significant at p < 0.001.

4.10. Standardized Solution (TQM)

TQM Strategic Systems (F1):			
V1=	0.697*F1 + 0.717 E1	V2=	0.717*F1 + 0.697 E2
V3=	0.548*F1 + 0.837 E3	V4=	0.661*F1 + 0.750 E4
V5=	0.640*F1 + 0.769 E5	V6=	0.745*F1 + 0.667 E6
V7=	*0.465**F1 + 0.886 E7		
TQM Operational Systems (F2):			
V8=	0.549*F2 + 0.836 E8	V9=	0.838*F2 + 0.546 E9
V10=	0.841*F2 + 0.541 E10	V11=	0.600*F2 + 0.800 E11
V12=	*0.329**F2 + 0.944 E12	**V13=**	*0.467**F2 + 0.885 E13
V14=	*0.437**F2 + 0.899 E14		

4.10. Standardized Solution (TQM) (continued)

TQM Information Systems (F3):

V15=	0.766*F3 + 0.643 E15	V16=	0.812*F3 + 0.584 E16
V17=	0.711*F3 + 0.703 E17	V18=	0.651*F3 + 0.759 E18
V19=	0.553*F3 + 0.833 E19	V20=	0.581*F3 + 0.814 E20

TQM Results (F4):

V21=	0.813*F4 + 0.582 E21	V22=	0.883*F4 + 0.469 E22
V23=	0.839*F4 + 0.544 E23	V24=	0.590*F4 + 0.807 E24
V25=	0.594*F4 + 0.804 E25	V26=	0.624*F4 + 0.782 E26
V27=	*0.462*F4 + 0.887 E27	**V28=**	*-0.483*F4 + 0.876 E28
V29=	0.583*F4 + 0.812 E29		

Table 4.11. Measurement Equations With Standard Errors and Test Statistics (ERM)

	Measurement Equation	Standard Error	t-value
ERM Strategic Systems (F5):			
V30=	2.085*F5 + 1.000 E30	0.136	15.288
V31=	2.253*F5 + 1.000 E31	0.140	16.114
V32=	1.855*F5 + 1.000 E32	0.151	12.252
V33=	2.393*F5 + 1.000 E33	0.166	14.434
V34=	1.815*F5 + 1.000 E34	0.148	12.229
V35=	2.174*F5 + 1.000 E35	0.163	13.357
V36=	2.257*F5 + 1.000 E36	0.165	13.687
ERM Operational Systems (F6):			
V37=	1.865*F6 + 1.000 E37	0.176	10.600
V38=	2.553*F6 + 1.000 E38	0.136	18.757
V39=	2.559*F6 + 1.000 E39	0.129	19.812
V40=	1.894*F6 + 1.000 E40	0.176	10.757
V41=	1.805*F6 + 1.000 E41	0.170	10.612
V42=	1.634*F6 + 1.000 E42	0.174	9.410
ERM Information Systems (F7):			
V43=	1.954*F7 + 1.000 E43	0.158	12.386
V44=	2.495*F7 + 1.000 E44	0.152	16.387
V45=	2.552*F7 + 1.000 E45	0.151	16.912
V46=	2.548*F7 + 1.000 E46	0.172	14.851
V47=	2.177*F7 + 1.000 E47	0.176	12.359
ERM Results (F8):			
V48=	*-0.532*F8 + 1.000 E48	0.103	-5.171
V49=	1.142*F8 + 1.000 E49	0.111	10.307
V50=	1.215*F8 + 1.000 E50	0.095	12.748
V51=	1.730*F8 + 1.000 E51	0.112	15.453
V52=	1.400*F8 + 1.000 E52	0.101	13.893

* All factor loadings are significant at $p < 0.001$.

4.12. Standardized Solution (ERM)

ERM Strategic Systems (F5):				
	V30=	0.794*F5 + 0.609 E30	V31=	0.822*F5 + 0.570 E31
	V32=	0.677*F5 + 0.736 E32	V33=	0.763*F5 + 0.647 E33
	V34=	0.676*F5 + 0.737 E34	V35=	0.722*F5 + 0.692 E35
	V36=	0.735*F5 + 0.678 E36		
ERM Operational Systems (F6):				
	V37=	0.602*F6 + 0.798 E37	V38=	0.902*F6 + 0.432 E38
	V39=	0.931*F6 + 0.364 E39	V40=	0.609*F6 + 0.793 E40
	V41=	0.603*F6 + 0.798 E41	V42=	0.545*F6 + 0.838 E42
ERM Information Systems (F7):				
	V43=	0.687*F7 + 0.727 E43	V44=	0.836*F7 + 0.549 E44
	V45=	0.853*F7 + 0.522 E45	V46=	0.783*F7 + 0.622 E46
	V47=	0.686*F7 + 0.728 E47		
ERM Results (F8):				
	V48=	-0.332*F8 + 0.943 E48	V49=	0.613*F8 + 0.790 E49
	V50=	0.724*F8 + 0.690 E50	V51=	0.837*F8 + 0.547 E51
	V52=	0.773*F8 + 0.634 E52		

After eliminating items that had low-item-construct loadings or loaded on multiple constructs, the NFI, NNFI, and CFI were iteratively used to determine whether the CFA models fitted the data well. First, to make certain that a given item represented the construct underlying each factor, a loading of 0.50 was used as the minimum cutoff. Second, to avoid problems with cross-loadings, the Lagrangian Multiplier (LM) test was used to identify significant cross-loadings (i.e., a loading on more than one factor). Under the univariate LM test, restrictions in the model are tested independently, and correlations among particular variables are not taken into account. As a result, there were more statistically significant LM χ^2s under this test than under the multivariate test. Thus, it was more judicious to base model respecifications on the multivariate LM test. As recommended, only one parameter was changed at every step (Joreskog and Sorbom 1993). Tables 4.15 and 4.16 explicitly note which variables were retained and dropped.

EQS takes a multivariate approach based on the LM test. The objective of the test was to determine if the models that better represent the data would result with certain parameters specified as free, rather than fixed, in subsequent runs. Model modifications were continued until all parameter estimates and overall fit measures were judged to be statistically and substantively satisfactory. The revised and final full first-order TQM and ERM CFA models, consisting of 13 and 10 measures, respectively, were reestimated (see Tables 4.13 and 4.14). The fit of the model is satisfactory based on all the criteria of χ^2, χ^2 /df, NFI, NNFI, and CFI.

Table 4.13. Goodness-of-Fit Indices for the Final First-Order TQM CFA Model

n	269 (Group 1: First Wave Responses)
Number of Latent Variables	4
Total Number of Observed Variables	13
Degrees of Freedom (df)	59
χ^2 Statistic	155.684
p-Value	0.001
χ^2 /df	2.64
Bentler-Bonett Normed Fit Index	0.907
Bentler-Bonett Nonnormed Fit Index	0.920
Comparative Fit Index	0.939

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	1.102002	1.000	193.56160
2	0.251602	1.000	1.05592
3	0.232535	1.000	0.66896
4	0.067727	1.000	0.59513
5	0.030976	1.000	0.58373
6	0.010985	1.000	0.58146
7	0.004907	1.000	0.58102
8	0.002018	1.000	0.58093
9	0.000905	1.000	0.58091

* All of the standardized residuals were below 0.218.
** Distribution of standardized residuals was symmetric and centered on zero.

Table 4.14. Goodness-of-Fit Indices for the Final First-Order ERM CFA Model

n	269 (Group 1: First Wave Responses)
Number of Latent Variables	4
Total Number of Observed Variables	10
Degrees of Freedom (df)	29
χ^2 Statistic	43.892
p-Value	0.0376
χ^2 /df	1.51
Bentler-Bonett Normed Fit Index	0.974
Bentler-Bonett Nonnormed Fit Index	0.986
Comparative Fit Index	0.991

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	2.734636	0.500	2.68313
2	0.993373	1.000	0.23925
3	0.097424	1.000	0.16472
4	0.012309	1.000	0.16384
5	0.003277	1.000	0.16378
6	0.000939	1.000	0.16378

* All of the standardized residuals were below 0.106.
** Distribution of standardized residuals was symmetric and centered on zero.

The revised models surpass the hypothesized models on all fit criteria (e.g., χ^2, χ^2/df, NFI, NNFI, and CFI) which confirms that the modifications were meaningful. The iterative summary shows that only 9 and 6 iterations were needed for a convergent solution. For EQS, there were two potential aspects of concern: 1) the appropriateness of the estimates; and 2) their statistical significance. The first step in assessing the fit of the individual parameters was to determine the plausibility of their estimated values. Any estimates falling outside the admissible range would signal that either the model was wrong or the input matrix lacked sufficient information. Examples of parameters

exhibiting unreasonable estimates would be: 1) correlations greater than 1.0; 2) standard errors that were abnormally large or small; and 3) negative variances. There were no examples of parameters exhibiting these types of unreasonable estimates. Furthermore, the sign and significance of the item loadings, along with an assessment of reliability indices for each factor using Cronbach's alpha also support the satisfactory fit of the models to the data (see Tables 4.15 and 4.16).

Table 4.15. The Final First-Order TQM CFA Model

	Measurement Equation		Standard Error	t-value
TQM Strategic Systems (F1):				
Cronbach's α = 0.643	V4=	1.294*F1 + 1.000 E4	0.121	10.705
	V6=	1.381*F1 + 1.000 E6	0.118	11.660
Standardized Solution:	V4=	0.659*F1 + 0.752 E4		
	V6=	0.719*F1 + 0.695 E6		
Items Dropped: V1, V2, V3, V5, V7				
TQM Operational Systems (F2):				
Cronbach's α = 0.865	V9=	1.748*F2 + 1.000 E9	0.108	16.167
	V10=	1.481*F2 + 1.000 E10	0.090	16.516
Standardized Solution:	V9=	0.873*F2 + 0.487 E9		
	V10=	0.888*F2 + 0.460 E10		
Items Dropped: V8, V11, V12, V13, V14				
TQM Information Systems (F3):				
Cronbach's α = 0.728	V19=	1.047*F3 + 1.000 E19	0.094	11.115
	V20=	1.529*F3 + 1.000 E20	0.117	13.026
Standardized Solution:	V19=	0.702*F3 + 0.712 E19		
	V20=	0.834*F3 + 0.553 E20		
Items Dropped: V15, V16, V17, V18				
TQM Results (F4):				
Cronbach's α = 0.872	V21=	2.090*F4 + 1.000 E21	0.127	16.493
	V22=	2.411*F4 + 1.000 E22	0.126	19.096
	V23=	1.917*F4 + 1.000 E23	0.115	16.700
	V24=	0.858*F4 + 1.000 E24	0.091	9.419
	V25=	0.927*F4 + 1.000 E25	0.097	9.569
	V26=	0.918*F4 + 1.000 E26	0.091	10.146
	V29=	0.800*F4 + 1.000 E29	0.088	9.100
Standardized Solution:	V21=	0.836*F4 + 0.548 E21		
	V22=	0.917*F4 + 0.399 E22		
	V23=	0.843*F4 + 0.537 E23		
	V24=	0.549*F4 + 0.836 E24		

Table 4.15. The Final First-Order TQM CFA Model (continued)

	V25= 0.557*F4 + 0.831 E25		
	V26= 0.584*F4 + 0.811 E26		
	V29= 0.534*F4 + 0.846 E29		
Items Dropped: V27, V28			
* All factor loadings are significant at p < 0.001			

Table 4.16. The Final First-Order ERM CFA Model

	Measurement Equation	Standard Error	t-value
ERM Strategic Systems (F5):			
Cronbach's α = 0.856	V30= 2.205*F5 + 1.000 E30	0.139	15.865
	V31= 2.447*F5 + 1.000 E31	0.142	17.257
Standardized Solution:	V30= 0.839*F5 + 0.544 E30		
	V31= 0.893*F5 + 0.451 E31		
Items Dropped: V32, V33, V34, V35, V36			
ERM Operational Systems (F6):			
Cronbach's α = 0.939	V38= 2.616*F6 + 1.000 E38	0.137	19.046
	V39= 2.635*F6 + 1.000 E39	0.130	20.211
Standardized Solution:	V38= 0.924*F6 + 0.382 E38		
	V39= 0.959*F6 + 0.284 E39		
Items Dropped: V37, V40, V41, V42			
ERM Information Systems (F7):			
Cronbach's α = 0.922	V44= 2.654*F7 + 1.000 E44	0.159	16.691
	V45= 2.877*F7 + 1.000 E45	0.155	18.551
Standardized Solution:	V44= 0.889*F7 + 0.458 E44		
	V45= 0.961*F7 + 0.275 E45		
Items Dropped: V43, V46, V47			
ERM Results (F8):			
Cronbach's α = 0.825	V49= 1.152*F8 + 1.000 E49	0.111	10.389
	V50= 1.218*F8 + 1.000 E50	0.096	12.749
	V51= 1.720*F8 + 1.000 E51	0.113	15.241
	V52= 1.398*F8 + 1.000 E52	0.101	13.811
Standardized Solution:	V49= 0.618*F8 + 0.786 E49		
	V50= 0.726*F8 + 0.688 E50		
	V51= 0.832*F8 + 0.554 E51		
	V52= 0.772*F8 + 0.635 E52		
Item Dropped: V48			
* All factor loadings are significant at p < 0.001			

The final models are tenable from a content and theoretical standpoint. Furthermore, the final first-order TQM and ERM CFA models

satisfied all of the measurement criteria. Cronbach's coefficient α is a widely used measure of scale reliability (Cronbach 1951). Typically, these coefficients should be 0.70 or higher for narrow constructs, and 0.55 or higher for moderately broad constructs such as those defined here (Van de Ven and Ferry 1979). All α values were higher than the minimum requirements. In terms of convergent validity, all the factor loadings for each individual indicator to its respective construct was positive, greater than 0.50, and highly significant ($p < 0.001$). Also, none of the LM χ^2 values were statistically significant. Meaning, there were no significant cross-loadings, demonstrating discriminant validity. Note, that all of the scales also have statistically significant and positive correlations with the primary outcome factors of TQM and ERM Results, respectively. Thus, criterion-related validity is supported for all the scales. Finally, all of the inter-factor correlations were positive and significant. This brings us to nomological validity, the focus of the next section.

4.3.4 Relationships Among the First-Order Factors

When a construct of interest is related to other constructs assessing a different but conceptually related construct by an established body of theory or according to a priori expectations, confirmation of the relationship predicted by the theory/expectations is evidence of nomological validity (Peter 1981). Nomological validity was assessed from the final measurement models using the inter-factor correlations (Bagozzi 1981a). Nomological validity was confirmed when the correlations between the factors, calculated in ϕ, were greater than zero. All correlations were statistically significant and positive, and

some of the correlations were very large (see Tables 4.17 and 4.18). The large correlations among some of the factors was not surprising since it was hypothesized a priori that these four underlying first-order factors are associated with a higher-order factor. The lack of any negative correlations among the factors indicates that a high value on one factor does not preclude a high value on another factor. In other words, the factors complement one another. This brings us to a further exploration of the structure of TQM and ERM.

Table 4.17. Correlations Among TQM Constructs

Factor 1:	TQM Strategic Systems	0.794[a]	Factor 1:	TQM Strategic Systems	0.766[a]
Factor 2:	TQM Operational Systems		Factor 3:	TQM Information Systems	
Factor 1:	TQM Strategic Systems	0.134[c]	Factor 2:	TQM Operational Systems	0.527[a]
Factor 4:	TQM Results		Factor 3:	TQM Information Systems	
Factor 2:	TQM Operational Systems	0.103[c]	Factor 3:	TQM Information Systems	0.157[b]
Factor 4:	TQM Results		Factor 4:	TQM Results	

[a] Correlations are statistically significant ($p < 0.001$)
[b] Correlations are statistically significant ($p < 0.05$)
[c] Correlations are statistically significant ($p < 0.10$)

Table 4.18. Correlations Among ERM Constructs

Factor 5:	ERM Strategic Systems	0.742[a]	Factor 5:	ERM Strategic Systems	0.567[a]
Factor 6:	ERM Operational Systems		Factor 7:	ERM Information Systems	
Factor 5:	ERM Strategic Systems	0.266[a]	Factor 6:	ERM Operational Systems	0.504[a]
Factor 8:	ERM Results		Factor 7:	ERM Information Systems	
Factor 6:	ERM Operational Systems	0.177[b]	Factor 7:	ERM Information Systems	0.145[b]
Factor 8:	ERM Results		Factor 8:	ERM Results	

[a] Correlations are statistically significant ($p < 0.001$)
[b] Correlations are statistically significant ($p < 0.05$)

4.4 Second-Order CFA Models

In the previous TQM and ERM factor analytic models, there were four factors that operated as independent variables. Each could be considered to be one level or one unidirectional arrow away from the

observed variables. These were subsequently termed first-order factors. However, theory argues for a higher level factor that is considered accountable for the lower-order factors. Let's examine the representation of this model in Figure 1.1.

This model essentially has the same first-order factor structure. However, in the present example, higher-order factors of TQM (F9) and ERM (F10) are hypothesized as accounting for or explaining all variance and covariance related to the first-order factors. As such, TQM and ERM are termed the second-order factors. It is important to note that TQM and ERM do not have their own set of measured indicators, rather, they are linked indirectly to those measuring the lower-order factors. Although the second-order models do not seem too different from the first-order models, more careful study of its structure reveals several technically distinctive characteristics that demand substantially different specifications for the two models.

One of the first things to notice is that although the first-order factor structure of these second-order CFA models appear basically the same as they did in the first-order CFA models, these factors now appear to operate as dependent as well as independent variables. However, this is not so because variables can only function as one or the other. The fact that the first-order factors operate as dependent variables means that their variances and covariances are no longer estimated parameters in the model. Such variation and covariation is presumed to be accounted for by the higher-order factors. As a reflection of this structure, there are no two-headed curved arrows linking the factors, thereby indicating that neither their factor covariances nor their variances are to be estimated.

A second feature of this type of model is the presence of single-headed arrows leading from the second-order factors to each of the first-order factors. These regression paths represent second-order factor loadings, and all are freely estimated. Recall, however, that either one of the regression paths or the variance of the independent factor can be estimated, but not both. Because the impact of TQM and ERM on each of their lower-order factors is of primary interest, the variance of the higher-order factors were constrained to 1.

Finally, the prediction of each of the first-order factors from the second-order factors is presumed not to be without error. Thus a residual disturbance term is associated with each of the lower-level factors. Disturbance terms for each of these endogenous variables in Figure 1.1 are not shown; however, it is assumed that any variation occurring due to factors not included in the model are due to these disturbance terms.

4.4.1 Identification

As a first step in determining whether the second-order models are identified, the number of parameters to be estimated are tallied up. In the second-order TQM CFA model, there are 9 first-order regression coefficients, 4 second-order regression coefficients, 13 measurement error variances, and 4 residual disturbances, making a total of 30. Given that there are 13 observed variables, there are 91 pieces of information in the sample variance-covariance matrix (13[13+1]/2=91). Therefore, this model is identified with 61 degrees of freedom.

Likewise, in the second-order ERM CFA model, there are 6 first-order regression coefficients, 4 second-order regression coefficients, 10 measurement error variances, and 4 residual terms, making a total of

24. Given that there are 10 observed variables, there are 55 pieces of information in the sample variance-covariance matrix (10[10+1]/2=55). Therefore, this model is identified with 31 degrees of freedom.

4.4.2 Testing the Second-Order CFA Models

The structural equation model is: $\eta = \Gamma\xi + \zeta$, where η is first-order factors (i.e., the four factors), Γ is the matrix of second-order factor loadings, ξ is the second-order factor, and ζ is the vector of unique variables for η. The overall model statistics indicate that the fit of the second-order models are as good as that of the first-order models (see Tables 4.10 and 4.20). This is as it should be, given that the second-order models merely specify higher-order factors to account for the correlations among the lower-order factors, rather than of these factors among themselves, as is the case with the first-order structures. The results given in Tables 4.21 and 4.22 show that the loadings of all four first-order factors on the second-order factors are positive and significant.

Table 4.19. Goodness-of-Fit Indices for the Second-Order TQM CFA Model

n	269 (Group 1: First Wave Responses)
χ^2 Statistic	158.105
Degrees of Freedom (df)	61
p-value	0.001
χ^2 /df	2.59
Normed Fit Index	0.905
Nonnormed Fit Index	0.922
Comparative Fit Index	0.939

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	0.532367	1.000	1.02330
2	0.183259	1.000	0.60741
3	0.050338	1.000	0.59231
4	0.013426	1.000	0.59043

Table 4.19. Goodness-of-Fit Indices for the Second-Order TQM CFA Model (continued)

5	0.008618	1.000	0.59006
6	0.002923	1.000	0.58997
7	0.001969	1.000	0.58995
8	0.000743	1.000	0.58995

* All of the standardized residuals were below 0.219.
** Distribution of standardized residuals was symmetric and centered on zero.

4.20. Goodness-of-Fit Indices for the Second-Order ERM CFA Model

n	269 (Group 1: First Wave Responses)
χ^2 Statistic	45.123
Degrees of Freedom (df)	31
p-value	.0486
χ^2 /df	1.46
Normed Fit Index	0.973
Nonnormed Fit Index	0.987
Comparative Fit Index	0.991

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	0.884631	1.000	0.96123
2	0.267911	1.000	0.29523
3	0.118659	1.000	0.17060
4	0.027235	1.000	0.16848
5	0.006514	1.000	0.16838
6	0.001941	1.000	0.16837
7	0.000529	1.000	0.16837

* All of the standardized residuals were below 0.103.
** Distribution of standardized residuals was symmetric and centered on zero.

Table 4.21. Second-Order TQM CFA Model

Measurement Equations With Standard Errors and Test Statistics

		Measurement Equation	Standard Error	t-value
TQM Strategic Systems (F1):				
	V4=	1.000 F1 + 1.000 E4		
	V6=	1.069*F1 + 1.000 E6	0.118	9.086
Standardized Solution:	V4=	0.671 F1 + 0.741 E4		

Table 4.21. Second-Order TQM CFA Model (continued)

	V6=	0.734*F1 + 0.680 E6		
TOM Operational Systems (F2):				
	V9=	1.000 F2 + 1.000 E9		
	V10=	0.858*F2 + 1.000 E10	0.061	14.010
Standardized Solution:	V9=	0.868 F2 + 0.497 E9		
	V10=	0.893*F2 + 0.449 E10		
TOM Information Systems (F3):				
	V19=	1.000 F3 + 1.000 E19		
	V20=	1.438*F3 + 1.000 E20	0.166	8.649
Standardized Solution:	V19=	0.708 F3 + 0.707 E19		
	V20=	0.827*F3 + 0.562 E20		
TOM Results (F4):				
	V21=	1.000 F4 + 1.000 E21		
	V22=	1.154*F4 + 1.000 E22	0.061	18.842
	V23=	0.917*F4 + 1.000 E23	0.055	16.766
	V24=	0.410*F4 + 1.000 E24	0.044	9.425
	V25=	0.443*F4 + 1.000 E25	0.046	9.579
	V26=	0.439*F4 + 1.000 E26	0.043	10.162
	V29=	0.383*F4 + 1.000 E29	0.042	9.116
Standardized Solution:	V21=	0.836 F4 + 0.548 E21		
	V22=	0.917*F4 + 0.398 E22		
	V23=	0.843*F4 + 0.538 E23		
	V24=	0.549*F4 + 0.836 E24		
	V25=	0.556*F4 + 0.831 E25		
	V26=	0.584*F4 + 0.812 E26		
	V29=	0.534*F4 + 0.846 E29		

Construct Equations With Standard Errors and Test Statistics

	Construct Equation	Standard Error	t-value
F1=	1.318*F9 + 1.000 D1	0.120	10.974
F2=	1.325*F9 + 1.000 D2	0.124	10.653
F3=	0.776*F9 + 1.000 D3	0.097	8.031
F4=	0.309*F9 + 1.000 D4	0.149	2.069[a]
Standardized Solution: F1=	1.000*F9 + 0.000 D1		
F2=	0.763*F9 + 0.647 D2		
F3=	0.736*F9 + 0.677 D3		
F4=	0.148*F9 + 0.989 D4		

[a] Second-order factor loading was statistically significant ($p < 0.05$); all other first- and second-order factor loadings were also statistically significant ($p < 0.001$)

Table 4.22. Second-Order ERM CFA Model

Measurement Equations With Standard Errors and Test Statistics

	Measurement Equation	Standard Error	t-value
ERM Strategic Systems (F5):			
	V30= 1.000 F5 + 1.000 E30		
	V31= 1.108*F5 + 1.000 E31	0.073	15.268
Standardized Solution:	V30= 0.840 F5 + 0.542 E30		
	V31= 0.892*F5 + 0.453 E31		
ERM Operational Systems (F6):			
	V38= 1.000 F6 + 1.000 E38		
	V39= 1.007*F6 + 1.000 E39	0.044	22.738
Standardized Solution:	V38= 0.925 F6 + 0.381 E38		
	V39= 0.959*F6 + 0.285 E39		
ERM Information Systems (F7):			
	V44= 1.000 F7 + 1.000 E44		
	V45= 1.083*F7 + 1.000 E45	0.070	15.511
Standardized Solution:	V44= 0.890 F7 + 0.457 E44		
	V45= 0.961*F7 + 0.276 E45		
ERM Results (F8):			
	V49= 1.000 F8 + 1.000 E49		
	V50= 1.058*F8 + 1.000 E50	0.115	9.235
	V51= 1.487*F8 + 1.000 E51	0.150	9.892
	V52= 1.210*F8 + 1.000 E52	0.126	9.574
Standardized Solution:	V49= 0.619 F8 + 0.785 E49		
	V50= 0.728*F8 + 0.686 E50		
	V51= 0.830*F8 + 0.557 E51		
	V52= 0.772*F8 + 0.636 E52		

Construct Equations With Standard Errors and Test Statistics

	Construct Equation	Standard Error	t-value
F5=	2.046*F10 + 1.000 D5	0.165	12.394
F6=	2.095*F10 + 1.000 D6	0.173	12.085
F7=	1.639*F10 + 1.000 D7	0.185	8.843
F8=	0.301*F10 + 1.000 D8	0.086	3.486
Standardized Solution: F5=	0.927*F10 + 0.375 D5		
F6=	0.801*F10 + 0.599 D6		
F7=	0.617*F10 + 0.787 D7		
F8=	0.261*F10 + 0.965 D8		

* All first- and second-order factor loadings are statistically significant ($p < 0.001$)

4.5 Cross-Validation and Non-Response Bias

This section deals with determining whether the factorial structures of the TQM and ERM CFA models replicate across independent samples of the same population. More explicitly, this addresses the

issue of non-response bias, and more importantly, cross-validation. In other words, are the TQM and ERM CFA models equivalent across the first wave of responses (Group 1; n=269) and the second wave of responses (Group 2; n=231).

In testing for invariance across both groups, sets of parameters were put to the test. The following set of parameters were of interest in answering questions related to group invariance: 1) factor loading paths (F--->V); and 2) factor covariances (F<--->F). Except in particular instances when, for example, it might be of interest to test for the invariant reliability of an assessment across groups, the equality of error variances and covariances is the least important hypothesis to test (Byrne 1988b; Bentler 1992a).

Tests of hypotheses related to group invariance begins and ends with scrutiny of the TQM and ERM measurement models. Invariance at the overall SEM level will exist if invariance in the measurement models can be demonstrated. In particular, the factor loadings and covariances for each measurement model were tested for their equivalence across groups. The EQS approach tests the validity of equality constraints multivariately rather than univariately, using the LM test. All equality constraints can be put to the test simultaneously.

When analyses focus on multigroup comparisons with constraints between the groups, it is imperative that parameters for all groups be estimated simultaneously. For this to be possible, model specifications for each group must exist in the same file. This is accomplished by stacking the input file for each group, one after the other. In this case, model specifications for the first wave of responses (Group 1)

appeared first, followed by those for the second wave of responses (Group 2).

Several unique features of the multigroup file need to be noted. First, the complete input file for Groups 1 and 2 were included. Each file terminated with the /END statement. Group 1 was described first, followed by Group 2. Second, in the /SPECIFICATIONS paragraph of the program, the GROUPS=2 statement was included. In multigroup files, the number of groups must always be specified. Finally, the /CONSTRAINTS paragraph was used to specify which parameters were to be held equal across the groups, and the /LMTEST command was used to indicate that these constraints were to be tested statistically using the LM test.

One important caveat in testing for invariance is that only estimated parameters can have equality constraints imposed upon them (i.e., fixed parameters are not eligible). Again, testing was limited to the factor loadings and covariances. In the /CONSTRAINTS paragraph, one equality specification statement was required for each parameter being constrained equal across groups. The parameter relative to Group 1 was specified in the first parenthesis and the parameter relative to Group 2 in the second parenthesis.

The results of the test for invariance are presented in Tables 4.23 and 4.24. Shown first are the goodness of fit statistics relative to the entire model, which comprises the two baseline models with equality constraints between them. As indicated by a CFI of 0.943 and 0.994 for the TQM and ERM CFA models, respectively, the multigroup models represent excellent fit to the data.

Table 4.23. Goodness-of-Fit Indices for the TQM Multigroup Model

Degrees of Freedom (df)	137
χ^2 Statistic	313.840
p-value	0.001
χ^2 /df	2.29
Bentler-Bonett Normed Fit Index	0.903
Bentler-Bonett Nonnormed Fit Index	0.935
Comparative Fit Index	0.943

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	1.103135	0.500	2.36164
2	0.598592	1.000	0.79590
3	0.122010	1.000	0.62191
4	0.035337	1.000	0.60262
5	0.011906	1.000	0.59950
6	0.004683	1.000	0.59902
7	0.001732	1.000	0.59894
8	0.000668	1.000	0.59893

* All of the standardized residuals were below 0.238.
** Distribution of standardized residuals was symmetric and centered on zero.

Table 4.24. Goodness-of-Fit Indices for the ERM Multigroup Model

Degrees of Freedom (df)	74
χ^2 Statistic	92.977
p-value	0.06716
χ^2 /df	1.26
Bentler-Bonett Normed Fit Index	0.973
Bentler-Bonett Nonnormed Fit Index	0.993
Comparative Fit Index	0.994

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	2.781111	0.500	2.80226
2	1.011499	1.000	0.28589
3	0.118917	1.000	0.17798
4	0.008907	1.000	0.17745
5	0.001346	1.000	0.17744
6	0.000239	1.000	0.17744

* All of the standardized residuals were below 0.171.
** Distribution of standardized residuals was symmetric and centered on zero.

Tables 4.25 and 4.26 relate to the validity of the imposed equality constraints. The program first echoes the constraints specified and then presents results for both univariate and multivariate tests of hypotheses. Associated with each constraint is an LM χ^2 statistic. In EQS, one simply has to check the related probability values to determine if any of the tests were statistically significant. For both measurement models, all probability values were greater than 0.05, thereby indicating that the hypothesized equality of the specified factor loadings and covariances held. Given these findings, all measures of TQM and ERM are operating in the same way for both groups. Thus, it would be appropriate to combine these two samples for a test of the full structural equation model.

4.25. Equality Constraints for the TQM Multigroup Model

Lagrangian Multiplier Test (For Releasing Constraints)

Constraints To Be Released Are:

Constraints from Group 2

```
Constraint:  1     (1,V4,F1) - (2,V4,F1)=0;
Constraint:  2     (1,V6,F1) - (2,V6,F1)=0;
Constraint:  3     (1,V9,F2) - (2,V9,F2)=0;
Constraint:  4     (1,V10,F2) - (2,V10,F2)=0;
Constraint:  5     (1,V19,F3) - (2,V19,F3)=0;
Constraint:  6     (1,V20,F3) - (2,V20,F3)=0;
Constraint:  7     (1,V21,F4) - (2,V21,F4)=0;
Constraint:  8     (1,V22,F4) - (2,V22,F4)=0;
Constraint:  9     (1,V23,F4) - (2,V23,F4)=0;
Constraint:  10    (1,V24,F4) - (2,V24,F4)=0;
Constraint:  11    (1,V25,F4) - (2,V25,F4)=0;
Constraint:  12    (1,V26,F4) - (2,V26,F4)=0;
Constraint:  13    (1,V29,F4) - (2,V29,F4)=0;
Constraint:  14    (1,F2,F1) - (2,F2,F1)=0;
Constraint:  15    (1,F3,F1) - (2,F3,F1)=0;
Constraint:  16    (1,F4,F1) - (2,F4,F1)=0;
Constraint:  17    (1,F3,F2) - (2,F3,F2)=0;
Constraint:  18    (1,F4,F2) - (2,F4,F2)=0;
```

4.25. Equality Constraints for the TQM Multigroup Model (continued)

Constraint: 19 (1,F4,F3) - (2,F4,F3)=0;

Univariate Test Statistics:

No.	Constraint	Chi-Square	Probability
1	Constraint: 1	0.065	0.799
2	Constraint: 2	1.613	0.204
3	Constraint: 3	0.001	0.971
4	Constraint: 4	0.012	0.912
5	Constraint: 5	2.367	0.124
6	Constraint: 6	0.231	0.631
7	Constraint: 7	0.105	0.746
8	Constraint: 8	0.008	0.930
9	Constraint: 9	1.188	0.276
10	Constraint: 10	1.126	0.289
11	Constraint: 11	0.621	0.431
12	Constraint: 12	0.806	0.369
13	Constraint: 13	0.196	0.658
14	Constraint: 14	0.004	0.950
15	Constraint: 15	0.124	0.724
16	Constraint: 16	2.367	0.124
17	Constraint: 17	0.454	0.501
18	Constraint: 18	0.479	0.489
19	Constraint: 19	0.928	0.336

Cumulative Multivariate Statistics :					Univariate Increment:	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Prob.
1	Constraint: 5	2.367	1	0.124	2.367	0.124
2	Constraint: 16	4.742	2	0.093	2.375	0.123
3	Constraint: 2	6.148	3	0.105	1.406	0.236
4	Constraint: 9	7.298	4	0.121	1.150	0.284
5	Constraint: 10	8.261	5	0.142	0.963	0.326
6	Constraint: 12	9.145	6	0.166	0.884	0.347
7	Constraint: 11	9.644	7	0.210	0.499	0.480
8	Constraint: 17	9.901	8	0.272	0.257	0.612
9	Constraint: 13	10.138	9	0.339	0.237	0.626
10	Constraint: 19	10.331	10	0.412	0.193	0.661
11	Constraint: 6	10.519	11	0.484	0.188	0.664
12	Constraint: 8	10.662	12	0.558	0.143	0.705
13	Constraint: 1	10.787	13	0.629	0.125	0.724
14	Constraint: 14	10.832	14	0.699	0.045	0.833
15	Constraint: 15	10.862	15	0.762	0.030	0.863
16	Constraint: 18	10.885	16	0.817	0.023	0.879
17	Constraint: 7	10.893	17	0.862	0.008	0.927
18	Constraint: 4	10.898	18	0.899	0.005	0.943
19	Constraint: 3	10.899	19	0.927	0.001	0.974

4.26. Equality Constraints for the ERM Multigroup Model

Lagrangian Multiplier Test (For Releasing Constraints)

Constraints To Be Released Are:

Constraints from Group 2

```
Constraint: 1     (1,V30,F5) - (2,V30,F5)=0;
Constraint: 2     (1,V31,F5) - (2,V31,F5)=0;
Constraint: 3     (1,V38,F6) - (2,V38,F6)=0;
Constraint: 4     (1,V39,F6) - (2,V39,F6)=0;
Constraint: 5     (1,V44,F7) - (2,V44,F7)=0;
Constraint: 6     (1,V45,F7) - (2,V45,F7)=0;
Constraint: 7     (1,V49,F8) - (2,V49,F8)=0;
Constraint: 8     (1,V50,F8) - (2,V50,F8)=0;
Constraint: 9     (1,V51,F8) - (2,V51,F8)=0;
Constraint: 10    (1,V52,F8) - (2,V52,F8)=0;
Constraint: 11    (1,F6,F5) - (2,F6,F5)=0;
Constraint: 12    (1,F7,F5) - (2,F7,F5)=0;
Constraint: 13    (1,F8,F5) - (2,F8,F5)=0;
Constraint: 14    (1,F7,F6) - (2,F7,F6)=0;
Constraint: 15    (1,F8,F6) - (2,F8,F6)=0;
Constraint: 16    (1,F8,F7) - (2,F8,F7)=0;
```

Univariate Test Statistics:

No.	Constraint	Chi-Square	Probability
1	Constraint: 1	0.425	0.514
2	Constraint: 2	0.254	0.614
3	Constraint: 3	0.227	0.634
4	Constraint: 4	0.156	0.693
5	Constraint: 5	0.669	0.414
6	Constraint: 6	0.065	0.799
7	Constraint: 7	0.903	0.342
8	Constraint: 8	0.815	0.367
9	Constraint: 9	0.792	0.374
10	Constraint: 10	1.137	0.286
11	Constraint: 11	1.848	0.174
12	Constraint: 12	1.648	0.199
13	Constraint: 13	0.560	0.454
14	Constraint: 14	0.000	0.987
15	Constraint: 15	0.444	0.505
16	Constraint: 16	0.004	0.949

4.26. Equality Constraints for the ERM Multigroup Model (continued)

Cumulative Multivariate Statistics :					Univariate Increment:	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Prob.
1	Constraint: 11	1.848	1	0.174	1.848	0.174
2	Constraint: 12	3.355	2	0.187	1.507	0.220
3	Constraint: 10	4.493	3	0.213	1.137	0.286
4	Constraint: 8	5.767	4	0.217	1.274	0.259
5	Constraint: 5	6.791	5	0.237	1.024	0.312
6	Constraint: 13	7.452	6	0.281	0.661	0.416
7	Constraint: 3	8.055	7	0.328	0.603	0.438
8	Constraint: 1	8.409	8	0.395	0.355	0.551
9	Constraint: 7	8.739	9	0.462	0.329	0.566
10	Constraint: 9	9.061	10	0.526	0.322	0.570
11	Constraint: 14	9.208	11	0.603	0.148	0.701
12	Constraint: 6	9.320	12	0.675	0.111	0.739
13	Constraint: 2	9.390	13	0.743	0.070	0.791
14	Constraint: 4	9.416	14	0.803	0.027	0.870
15	Constraint: 15	9.430	15	0.854	0.014	0.905
16	Constraint: 16	9.450	16	0.894	0.020	0.887

Extrapolation methods of nonresponses bias are based on the assumption that subjects who respond less readily (i.e., answering later) are more like nonrespondents. The most common type of extrapolation is carried over successive waves of a questionnaire. A wave refers to the response generated by a stimulus which was a reminder postcard in this dissertation (Armstrong and Overton 1977). Persons who responded in the second wave are assumed to have responded because of the stimulus (i.e., reminder postcard) and are expected to be similar to nonrespondents. The evidence of a lack of nonresponse bias exists since the TQM and ERM CFA models proved to be equivalent across the first and second wave of responses.

4.6 The Full Structural Equation Model

In contrast to the CFA models, which comprised only the measurement components, the full structural equation model in Figure 1.1

encompasses both the measurement models and a structural model. Accordingly, the full model embodies a system of variables whereby latent factors are regressed on other factors as dictated by theory and observed measures on appropriate factors. In other words, in the full SEM, certain latent variables are connected by one-way causal arrows, the directionality of which reflects hypotheses bearing on the causal structure of variables in the model (indicated by γ_1 and the βs in Figure 1.1).

The structural component of the model in Figure 1.1 represents the hypothesis that ERM derives from TQM (γ_1). Furthermore, TQM Strategic Systems, TQM Operational Systems, TQM Information Systems, and TQM Results are derived from the higher-order factor of TQM (β_1, β_2, β_3, and β_4, respectively). Likewise, ERM Strategic Systems, ERM Operational Systems, ERM Information Systems, and ERM Results are derived from the higher-order factor of ERM (β_5, β_6, β_7, and β_8, respectively). See Section 3.2 for more detail regarding the specific research hypotheses.

Because ERM and all 8 of the first-order factors have one-way arrows pointing at them, they are identified as dependent variables in the model. A residual disturbance term associated with the regression of ERM on TQM is captured by a disturbance term for ERM (D10). Likewise, residual errors associated with the regression of the first-order factors on their higher-order factors are captured by disturbance terms for each first-order factor (D1-D8).

As usual, associated with each observed measure is an error term, the variance of which is of interest. Because the observed measures are dependent variables in the model, their variances are not estimated.

Finally, to establish the scale for each unmeasured factor in the model (and for purposes of identification), the first of each set of regression paths is fixed to 1. The path selection for this constraint was purely arbitrary.

Given that there are 23 observed measures, there are 276 (23[23+1]/2=276) pieces of information from which to derive the parameters of the model. Counting up the number of parameters to be estimated in the model, there are 55 parameters to be estimated: 16 measurement regression paths (F--->V; the factor loadings); 7 structural regression paths (F--->F); 23 error variances (Es); and 9 disturbance variances (Ds). Therefore, this model is identified with 221 degrees of freedom.

The final task was to translate the full model into a set of equations. These were as follows:

```
V4=1F1+E4
V6=1*F1+E6

V9=1F2+E9
V10=1*F2+E10

V19=1F3+E19
V20=1*F3+E20

V21=1F4+E21
V22=1*F4+E22
V23=1*F4+E23
V24=1*F4+E24
V25=1*F4+E25
V26=1*F4+E26
V29=1*F4+E29

V30=1F5+E30
V31=1*F5+E31

V38=1F6+E38
V39=1*F6+E39

V44=1F7+E44
V45=1*F7+E45
```

```
V49=1F8+E52
V50=1*F8+E53
V51=1*F8+E54
V52=1*F8+E55

F1=1F9+D1
F2=1*F9+D2
F3=1*F9+D3
F4=1*F9+D4

F5=1F10+D5
F6=1*F10+D6
F7=1*F10+D7
F8=1*F10+D8

F10=*F9+D10
```

where * represents parameters to be estimated.

4.6.1 Testing the Full Structural Equation Model

In Section 4.5, the null hypothesis (H_0) that $\Sigma_1 = \Sigma_2 = \ldots \Sigma_G$ was tested, where Σ is the population-covariance matrix, and *G* is the number of groups (G=2; Group 1=first wave of responses, n=269; Group 2=second wave of responses, n=257). Since H_0 was rejected, the groups were considered to be equivalent, and thus tests for invariance were unjustified. Consequently, group data can be pooled and all subsequent investigative work can be based on a single-group analysis (Joreskog 1971; Byrne 1994). A total of 531 questionnaires were returned, yielding a response rate of 18.03%. However, 5 of the questionnaires were unusable. Thus, the effective response rate was 17.86% (526 responses). Table 4.27 shows the sample characteristics of the pooled data.

Table 4.27. Pooled Data (n=526)

	Mean	Std. Dev.	Median	Min.	Max.
Respondent's Experience in Current Position (Years)[a]:	5.971	5.442	4	0.5	40
Number of Employees[b]:	333.301	377.570	225	15	3,500
Plant Size (Square Feet)[c]:	177,369.860	211,472.717	120,000	10,000	2,000,000
1995 Sales Volume ($)[d]:	57,160,865.83	85,306,497.06	31,000,000	1,000,000	1,076,593,000
1996 Sales Volume ($)[e]:	64,530,752.8	91,457,710.89	36,000,000	1,000,000	998,789,000
Average Age of Production Equipment (Years)[f]:	10.536	7.826	8	0.5	50

[a] n = 514, [b] n = 332, [c] n = 322, [d] n = 451, [e] n = 455, [f] n = 515

* n varies because data elements were unavailable for some observations

Held Title of Plant Manager:	209
Held Other Title (e.g., V.P., President, C.E.O, G.M., etc.):	312
No responses to title:	5

Union Representation:	175
Non-Union Representation:	351

Number of Plants by Region: Michigan (103); Ohio (38); Illinois (27); Indiana (23); Kentucky (20); Tennessee (20); Virginia (12); North Carolina (8); Pennsylvania (8); Wisconsin (8); Arkansas (7); Georgia (7); Missouri (6); New York (5); Texas (5); California (4); Connecticut (4); Iowa (4); Florida (3); Minnesota (3); New Hampshire (3); Oklahoma (2); South Carolina (2); Louisiana (1); Mississippi (1); Nebraska (1); Utah (1)

Parent Firm**:

Publicly Traded	207
Foreign-Owned Subsidiary/Transplant	88
Privately Owned	242
Joint Venture	24

** Note, more than one type of ownership might apply to a parent firm.

Estimation of the full SEM model resulted in an overall $\chi^2_{(221)}$ value of 632.093, with a CFI value of 0.938 (see Table 4.28). Turning first to these goodness-of-fit statistics, it is concluded that there is a high degree of fit in the model. As a point of interest, the iterative summary was included in Table 4.28. Only 7 iterations were needed for a convergent solution, thereby indicating that in general the specified model and the default start values were adequate.

Table 4.28. Goodness-of-Fit Indices for the Full Structural Equation Model

n	526 (First & Second Wave Responses)
Number of Latent Variables	8
Total Number of Observed Variables	23
Degrees of Freedom (df)	221
χ^2 Statistic	632.093
p-value	0.001
χ^2 /df	2.86
Bentler-Bonett Normed Fit Index	0.909
Bentler-Bonett Nonnormed Fit Index	0.929
Comparative Fit Index	0.938

Iterative Summary:

Iteration	Parameter ABS Change	Alpha	Function
1	0.607356	1.000	2.36769
2	0.198926	1.000	1.47028
3	0.082421	1.000	1.21307
4	0.012682	1.000	1.20429
5	0.004032	1.000	1.20402
6	0.001064	1.000	1.20399
7	0.000500	1.000	1.20399

* All of the standardized residuals were below 0.369.
** Distribution of standardized residuals was symmetric and centered on zero.

Of substantial interest in the computer output are the LM statistics (see Table 4.29). The LM test incorporated a command to limit statistics to: 1) misspecified paths (i.e., paths that are not specified, but should be) that flow from independent to dependent factors and from one dependent factor to another; and 2) misspecified covariances among the disturbance terms. The omitted paths leading from one latent variable to another are listed in the column labeled "Parameter."

Table 4.29. Multivariate Lagrangian Multiplier Test for Full SEM

Cumulative Multivariate Statistics:					Univariate Increment:	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Probability
1	D8,D4	101.793	1	0.000	101.793	0.000
2	F7,F2	111.942	2	0.000	10.149	0.001
3	F2,F6	120.201	3	0.000	8.258	0.004

The easiest way to identify the path being targeted as a misspecified parameter is to conceptualize the causal flow as going from the second factor in a pair of latent factors to the first factor in the pair. For example, the second parameter specified in the output is F7,F2. This parameter is interpreted as the structural path flowing from F2 (TQM Operational Systems) to F7 (ERM Information Systems). These results suggest that if this path were to be specified in the model, TQM Operational Systems would have a substantial impact on ERM Information Systems. However, parameters identified by EQS as belonging in a model are based on statistical criteria only. Of more importance is that their inclusion be substantively meaningful. In this example, the incorporation of this path into the model would not be supported theoretically. Likewise, the other two parameters in the output (i.e., D8,D4; F2,F6) are not substantively meaningful. Thus, all three parameters were ignored with respect to model respecification. Considering the excellent fit of the model to the data and the small magnitude and atheoreticalness of the LM χ^2 statistics, it can be argued that no additions to the model are required.

Thus far, discussion related to model fit has considered only the addition of parameters to the model. However, another side to the question of fit, particularly as it pertains to a full model, is the extent to which certain initially hypothesized paths may be redundant to the model. One way of determining such redundancy is to examine the statistical significance of all structural parameter estimates. This information is presented in Tables 4.30 and 4.31.

Table 4.30. Measurement Equations With Standard Errors and Test Statistics (Full SEM)

	Measurement Equation	Standard Error	t-value
TOM Strategic Systems (F1):			
V4=	1.000 F1 + 1.000 E4		
V6=	1.002*F1 + 1.000 E6	0.075	13.283
Standardized Solution: V4=	0.699 F1 + 0.715 E4		
V6=	0.711*F1 + 0.703 E6		
TOM Operational Systems (F2):			
V9=	1.000 F2 + 1.000 E9		
V10=	0.850*F2 + 1.000 E10	0.045	18.787
Standardized Solution: V9=	0.878 F2 + 0.479 E9		
V10=	0.849*F2 + 0.529 E10		
TOM Information Systems (F3):			
V19=	1.000 F3 + 1.000 E19		
V20=	1.368*F3 + 1.000 E20	0.105	12.973
Standardized Solution: V19=	0.721 F3 + 0.693 E19		
V20=	0.846*F3 + 0.533 E20		
TOM Results (F4):			
V21=	1.000 F4 + 1.000 E21		
V22=	1.141*F4 + 1.000 E22	0.042	27.162
V23=	0.880*F4 + 1.000 E23	0.038	22.989
V24=	0.432*F4 + 1.000 E24	0.032	13.487
V25=	0.460*F4 + 1.000 E25	0.033	14.041
V26=	0.407*F4 + 1.000 E26	0.032	12.813
V29=	0.365*F4 + 1.000 E29	0.029	12.409
Standardized Solution: V21=	0.848 F4 + 0.529 E21		
V22=	0.921*F4 + 0.390 E22		
V23=	0.821*F4 + 0.571 E23		
V24=	0.556*F4 + 0.831 E24		
V25=	0.574*F4 + 0.819 E25		
V26=	0.533*F4 + 0.846 E26		
V29=	0.518*F4 + 0.855 E29		
ERM Strategic Systems (F5):			
V30=	1.000 F5 + 1.000 E30		
V31=	1.044*F5 + 1.000 E31	0.048	21.916

Table 4.30. Measurement Equations With Standard Errors and Test Statistics (Full SEM) (continued)

Standardized Solution:	V30=	0.868 F5 + 0.497 E30		
	V31=	0.864*F5 + 0.503 E31		
ERM Operational Systems (F6):				
	V38=	1.000 F6 + 1.000 E38		
	V39=	1.022*F6 + 1.000 E39	0.032	31.562
Standardized Solution:	V38=	0.917 F6 + 0.398 E38		
	V39=	0.971*F6 + 0.240 E39		
ERM Information Systems (F7):				
	V44=	1.000 F7 + 1.000 E44		
	V45=	1.042*F7 + 1.000 E45	0.042	24.998
Standardized Solution:	V44=	0.915 F7 + 0.404 E44		
	V45=	0.953*F7 + 0.303 E45		
ERM Results (F8):				
	V49=	1.000 F8 + 1.000 E49		
	V50=	0.980*F8 + 1.000 E50	0.073	13.378
	V51=	1.455*F8 + 1.000 E51	0.099	14.723
	V52=	1.115*F8 + 1.000 E52	0.080	13.859
Standardized Solution:	V49=	0.650 F8 + 0.760 E49		
	V50=	0.713*F8 + 0.701 E50		
	V51=	0.846*F8 + 0.533 E51		
	V52=	0.748*F8 + 0.663 E52		

* All factor loadings are statistically significant ($p < 0.001$)

4.31. Construct Equations With Standard Errors and Test Statistics (Full SEM)

	Construct Equation	Standard Error	t-value
TQM Strategic Systems (F1)=	1.000 F9 + 1.000 D1		
TQM Operational Systems (F2)=	1.033*F9 + 1.000 D2	0.080	12.856
TQM Information Systems (F3)=	0.643*F9 + 1.000 D3	0.062	10.365
TQM Results (F4)=	0.247*F9 + 1.000 D4	0.081	3.071
ERM Strategic Systems (F5)=	1.000 F10 + 1.000 D5		
ERM Operational Systems (F6)=	0.922*F10 + 1.000 D6	0.067	13.769
ERM Information Systems (F7)=	0.848*F10 + 1.000 D7	0.069	12.286
ERM Results (F8)=	0.141*F10 + 1.000 D8	0.030	4.736
ERM (F10)=	0.789*F9 + 1.000 D10	0.093	8.486
Standardized Solution:			
TQM Strategic Systems (F1)=	1.000 F9 + 0.000 D1		
TQM Operational Systems (F2)=	0.785*F9 + 0.620 D2		
TQM Information Systems (F3)=	0.741*F9 + 0.672 D3		
TQM Results (F4)=	0.157*F9 + 0.988 D4		
ERM Strategic Systems (F5)=	0.939 F10 + 0.345 D5		
ERM Operational Systems (F6)=	0.769*F10 + 0.639 D6		
ERM Information Systems (F7)=	0.654*F10 + 0.757 D7		
ERM Results (F8)=	0.253*F10 + 0.967 D8		
ERM (F10)=	0.484*F9 + 0.875 D10		

All structural parameter estimates were also statistically significant ($p < 0.001$)

Examining the test statistics associated with the structural estimates (see Table 4.31), it can be seen that all are significant. The limiting factor in using these statistics as a basis for pinpointing redundant parameters, however, is that they represent a univariate test of significance. When sets of parameters are to be evaluated, a more appropriate approach is to implement a multivariate test of statistical significance. Indeed, the EQS program is unique in its provision of the Wald test for this very purpose. Essentially, the Wald test ascertains whether sets of parameters, specified as free in the model, could in fact be simultaneously set to zero without substantial loss in model fit. It does so by taking the least significant parameter (i.e., the one with the smallest test statistic) and adding other parameters in such a way that the overall multivariate test yields a set of free parameters that with high probability can simultaneously be dropped from the model in future EQS runs without a significant degradation in model fit (Bentler 1992a). To test multivariately for redundant structural paths in the model, the Wald test was added to the EQS input and the model was reestimated. Not surprisingly, the Wald test did not identify any parameters as being redundant; meaning, none of the free parameters were dropped in the process.

4.7 Testing the Structures Between TQM and ERM

There was no reason, a priori, to believe that the structures associated with TQM and ERM based systems are different; therefore, the structures between TQM and ERM based systems were hypothesized to be similar or parallel one another. More specifically, this was reflected in the following research hypotheses (see Section 3.2 for more detail):

Hypothesis 10 (H10): $\beta_1 - \beta_5 = 0$, $p < 0.05$
Hypothesis 11 (H11): $\beta_2 - \beta_6 = 0$, $p < 0.05$
Hypothesis 12 (H12): $\beta_3 - \beta_7 = 0$, $p < 0.05$
Hypothesis 13 (H13): $\beta_4 - \beta_8 = 0$, $p < 0.05$

EQS permits equality constraints to be imposed on estimated parameters within the same sample. Equality constraints corresponding to the above research hypotheses were specified in the /CONSTRAINTS section. Equality constraints can be imposed on any of the free variances, covariances, and measurement or construct equation parameters. The focus of this test was on the construct equation parameters associated with the above research hypotheses. However, such parameters must be associated with asterisks (*) in the overall SEM to denote a value to be estimated. If a parameter defined in the /CONSTRAINTS section is not a free parameter in the overall SEM model, then an error message will be printed and the program will terminate. It will not continue into the computational section. The error must be corrected, and the job resubmitted.

From Section 4.6, in testing the full SEM, the first of each set of regression paths was fixed to 1.0 to establish the scale for each unmeasured factor in the model. This was done for purposes of identification. For example, F1=1F9+D1 and F5=1F10+D5. The path selection for these constraints was purely arbitrary. However, in order to test the constraint that F1 (TQM Strategic Systems) and F5 (ERM Strategic Systems) parallel one another, these parameters must be freed. Therefore, asterisks were placed in these construct equations which represents parameters to be estimated (e.g., F1=1*F9+D1 and F5=1*F10+D5). Subsequently, F9 (TQM) and F10 (ERM) were allowed to covary and their variances were fixed at one. This was a necessary

condition in the full SEM model in order to test the four equality constraints simultaneously. Table 4.32 relates to the validity of the imposed equality constraints.

4.32 Equality Constraints for the TQM and ERM Parallel Structures

Lagrange Multiplier Test (For Releasing Constraints)

Constraints To Be Released Are:

Constraint: 1 (F1,F9) - (F5,F10) = 0;
Constraint: 2 (F2,F9) - (F6,F10) = 0;
Constraint: 3 (F3,F9) - (F7,F10) = 0;
Constraint: 4 (F4,F9) - (F8,F10) = 0;

Univariate Test Statistics:

No	Constraint	Chi-Square	Probability
1	Constr: 1	26.564	0.000
2	Constr: 2	11.119	0.001
3	Constr: 3	34.092	0.000
4	Constr: 4	0.468	0.494

Cumulative Multivariate Statistics					Univariate Increment	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Probability
1	Constr: 3	34.092	1	0.000	34.092	0.000
2	Constr: 1	65.887	2	0.000	31.794	0.000
3	Constr: 2	85.172	3	0.000	19.286	0.000
4	Constr: 4	85.219	4	0.000	0.047	0.829

Turning to the univariate LM χ^2 statistics and related probability values associated with each quality constraint, it is shown that only the fourth constraint was invariant across both TQM and ERM based systems. The univariate and multivariate analyses for the first three constraints reflected the noninvariance of the parallel structural paths across the TQM and ERM based systems.

4.8 Common Method and Omitted Variable Bias

A single respondent from each plant, typically holding the title of plant manager, completed the questionnaire. Asking a single informant to make judgments increases the likelihood of respondents to seek out consistency in their responses and increases random measurement error (Roth and Miller 1994). The bias associated with using a single informant is often referred to as the problem of common method bias. However, the high level of the respondents and the size of their plants was used to help moderate the mono-respondent problem. Furthermore, some factors may not have been explicitly modeled in the study. Perhaps the theory was not developed to the point of giving a complete model specification. This would create model specification error which would further bias the results.

One would expect that if an unobservable variable or mono-respondent problem existed which biased the data, a common error variance would be generated between the items actually measured (Hughes, Price, and Marrs 1986; Bollen 1989). A test to insure that common method and omitted variables were not biasing the results was conducted. Specifically, a test of the theta delta (Θ_δ) matrix for each final CFA model was performed. The TQM and ERM CFAs were rerun to allow the errors of the measures (i.e., δs) to covary. In other words, the zero-correlation constraints for the relevant off-diagonal elements in the Θ_δ matrix were released. EQS produces univariate and multivariate χ^2 statistics that permits evaluation of the appropriateness of these type of specified restrictions. It also yields a parameter change statistic that represents the value that would be obtained if a particular fixed

parameter were freely estimated in a future run. The LM test procedure provides for several options (Bentler 1989, 1992a). One of these options, the SET command, was included in the present analysis. This command allowed the LM test to be limited to only a subset of the fixed parameters in the model. In the present case, the parameters of interest were the error covariances (e.g., SET=PEE). The letter P stands for the PHI matrix and the double letters EE for the covariance between two error terms (i.e., correlated errors). In Tables 4.33 and 4.34, the cumulative multivariate statistics, along with their accompanying univariate increments, show that there are very few malfitting parameters.

Table 4.33. TQM CFA Model Multivariate LM Test With Θ_δ Matrix Released

Cumulative Multivariate Statistics					Univariate Increment	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Probability
1	E22,E21	58.145	1	0.000	58.145	0.000
2	E23,E22	87.300	2	0.000	29.154	0.000
3	E23,E21	139.921	3	0.000	52.622	0.000
4	E19,E10	146.789	4	0.000	6.868	0.009
5	E9,E6	151.420	5	0.000	4.631	0.031

Table 4.34. ERM CFA Model Multivariate LM Test With Θ_δ Matrix Released

Cumulative Multivariate Statistics					Univariate Increment	
Step	Parameter	Chi-Square	D.F.	Probability	Chi-Square	Probability
1	E53,E52	17.113	1	0.000	17.113	0.000
2	E45,E38	22.432	2	0.000	5.319	0.021
3	E54,E45	26.751	3	0.000	4.319	0.038

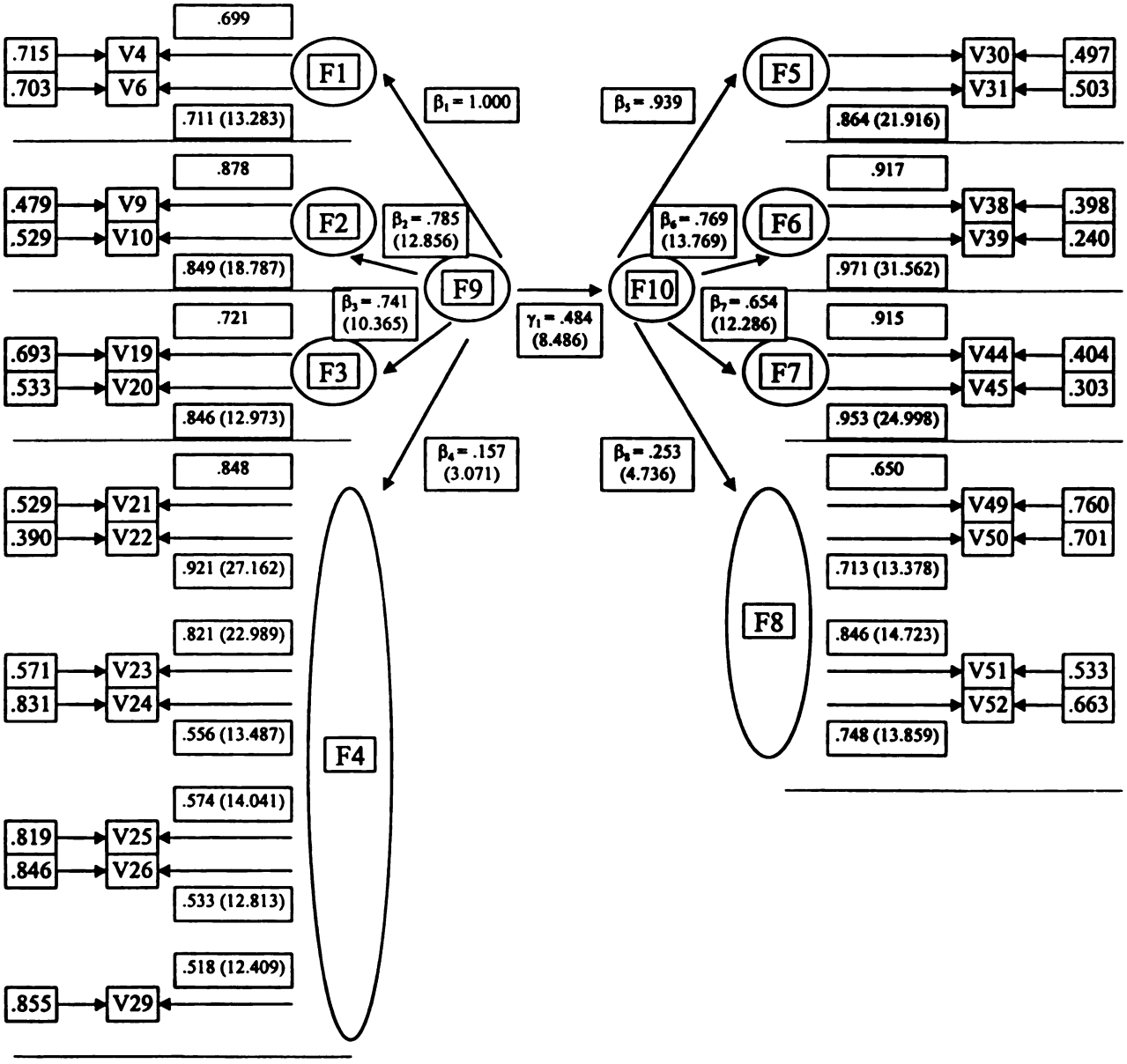
Provided with this information, the model could have been respecified. However, none of the error covariances were respecified as

freely estimated parameters for the following reasons. The first important note is the small drop in the χ^2 values for the TQM and ERM CFA models when their respective Θ_δ matrices are released. Statistically, they yield small χ^2 values to already well-fitting models. Recall in Section 4.3.3, the fit of the final TQM and ERM CFA models was satisfactory based on all the criteria (e.g., CFI=.939 and .991 for the TQM and ERM CFA models, respectively). The decreases in χ^2 that would have been achieved by specifying the error covariances as freely estimated parameters would not have represented highly significant improvements in model fit. Furthermore, from a substantive point of view, they represent correlated errors among subscales of the same measuring instrument. CFA and a strong theoretical foundation usually assume that the errors are uncorrelated (Dillon and Goldstein 1984). Taken together, these findings, along with already well-fitting CFA models, provide strong support for a model that should not include error covariances among the subscales of the same measurement instrument. The absence of a significant improvement in model fit when these constraints were released demonstrated the absence of such a bias. The LM tests showed that no significant difference between the fit of the new (i.e., correlated errors) and original CFA models would be found. Thus, the proposition that common method and omitted variables were generating biases was rejected because no evidence was found to suggest a systematic bias overall.

4.9 Summary of Data Analysis Findings

Figure 4.1 summarizes the results of the data analysis performed in this chapter and the figure represents the final full SEM. Table 4.35 follows the SEM and clarifies the lexicon used in Figure 4.1.

Figure 4.1. The Final Full Structural Equation Model (SEM)



* Each first-order factor and F10 has a disturbance term associated with it. D1=0.000, D2=.620, D3=.672, D4=.988, D5=.345, D6=.639, D7=.757, D8=.967, and D10=.875.

( ) t-values in parentheses

Table 4.35. Labels for Final Full SEM Model (Figure 4.1)

FACTOR (Fs) & VARIABLE (Vs) LABELS

F1 = Factor 1 = TOM Strategic Systems

V4: Adequate resources are provided to carry out quality improvements within your plant
V6: Key factors for building and maintaining customer relationships are identified and used by your plant

F2 = Factor 2 = TOM Operational Systems

V9: An adequate amount of training in quality awareness is provided to hourly/direct labor employees within your plant
V10: An adequate amount of training in quality awareness is provided to managers and supervisors within your plant

F3 = Factor 3 = TOM Information Systems

V19: Procedures have been developed for monitoring key indicators of plant performance
V20: Procedures have been developed for monitoring key indicators of customer satisfaction

F4 = Factor 4 = TOM Results

V21: After-sales customer complaints
V22: Customer rejection of our products (e.g., manufacturing defects)
V23: Defect rates/cost
V24: Employee absenteeism
V25: Cost of quality (e.g., inspection and testing)
V26: Employee grievances
V29: Total cost of purchased parts

F5 = Factor 5 = ERM Strategic Systems

V30: Environmental goals are clearly communicated to all plant personnel
V31: Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant

F6 = Factor 6 = ERM Operational Systems

V38: An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant
V39: An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant

Table 4.35. Labels for Final Full SEM Model (Figure 4.1) (continued)

F7 = Factor 7 = ERM Information Systems

V44: Information about best-in-class environmental performance is tracked and recorded by your plant
V45: Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis

F8 = Factor 8 = ERM Results

V49: Volume of wastewater discharges
V50: Tons of solid waste landfilled
V51: Volume of hazardous waste
V52: Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur oxides, etc.)

4.9.1 Hypotheses 1-4

In Section 2.4, using the traits associated with Total Quality Management (TQM), and comparing these traits to the various constructs found in the literature, the Malcolm Baldrige National Quality Award (MBNQA) framework was determined to best fit the definition of TQM. Since the MBNQA was the most consistent definition of TQM, it was used as the operational framework of TQM for the purposes of this dissertation. For example, TQM was operationalized using four multi-item scales which corresponded to the three subsystems and the results category associated with the MBNQA framework. The 1997 MBNQA framework is described as three related subsystems (Evans 1997): 1) the "strategic" categories of *leadership* (1.0), *strategic planning* (2.0), and *customer/market focus* (3.0); 2) the "operational" categories of *human resource development* (5.0) and *process management* (6.0) (which

lead to "results" (7.0)); and 3) the "information" category (4.0) that serves as the foundation for the other two subsystems.

In light of this discussion, it was hypothesized that the presence of TQM Strategic Systems (F1), TQM Operational Systems (F2), TQM Information Systems (F3), and TQM Results (F4) encourages the emergence and acceptance of TQM (F9); thus, β_1, β_2, β_3, and β_4 were proposed to be positive (see Figure 1.1). More specifically:

Hypothesis 1 (H1): $\beta_1 > 0$, $p < 0.05$
Hypothesis 2 (H2): $\beta_2 > 0$, $p < 0.05$
Hypothesis 3 (H3): $\beta_3 > 0$, $p < 0.05$
Hypothesis 4 (H4): $\beta_4 > 0$, $p < 0.05$

Each of these specific research hypotheses are now examined.

4.9.1.1 Hypothesis 1

The structural path from TQM (F9) to TQM Strategic Systems (F1) was positive and significant as hypothesized ($\beta_1 = 1.000$). The TQM Strategic Systems factor includes and examines: senior executives' personal leadership and involvement in creating and sustaining a customer focus and clear and visible quality values; how the values and expectations are integrated into the company's management system; the company's planning process and how all key quality requirements are integrated into overall business planning; the company's short- and long-term plans and how quality and performance requirements are deployed to all work units; how the company determines requirements and expectations of customers and markets; and how the company enhances relationships with customers and determines their satisfaction (MBNQA 1997).

TQM Strategic Systems (F1) retained two measures in the final TQM CFA measurement model: 1) Adequate resources are provided to carry out

quality improvements within your plant (V4); and 2) Key factors for building and maintaining customer relationships are identified and used by your plant (V6). The first measure (V4) includes issues as they pertain to strategic planning. The second measure (V6) includes issues as they pertain to customer and market focus.

Based on the literature, TQM requires that product quality be defined from the customer's viewpoint. For example, exceeding the customer's expectations can only be accomplished when organizations strategically plan and dedicate their resources to quality improvements (Ahire, Landeros, and Golhar 1995). Furthermore, TQM is based on the premise that the customer is always right. As a result, TQM requires the adoption of response systems to handle the most basic of customer concerns or requirements (Baum 1990; Feldman 1991). This study provides empirical support for the need to provide resources for quality improvement and to use key factors for building customer relationships in a TQM based system.

4.9.1.2 Hypothesis 2

The structural path from TQM (F9) to TQM Operational Systems (F2) was positive and significant as hypothesized (β_2 = .785, t = 12.856). The TQM Operational Systems factor includes and examines: how the work force is enabled to develop and utilize its full potential, aligned with the company's objectives; the company's efforts to build and maintain an environment conducive to full participation, and personal and organizational growth; the key aspects of process management, including customer-focused design, product and service delivery processes, support services and supply management involving all work units, including

research and development; and how key processes are designed, effectively managed, and improved to achieve higher performance (MBNQA 1997).

TQM Operational Systems (F2) retained two measures in the final TQM CFA measurement model: 1) An adequate amount of training in quality awareness is provided to hourly/direct labor employees within your plant (V9); and 2) An adequate amount of training in quality awareness is provided to managers and supervisors within your plant (V10). Both of the remaining measures include issues as they pertain to human resource development.

TQM demands that all aspects of human resource management (e.g., training and development) assume critical roles (Ahire, Landeros, and Golhar 1995). Several case studies and anecdotal examples identify that training and development at all levels as the single best strategy to improve quality and productivity (Juran 1981a, 1981b; Ebrahimpour 1985; Lee and Ebrahimpour 1985). This study empirically supports the need for human resource development in a TQM based system.

4.9.1.3 Hypothesis 3

The structural path from TQM (F9) to TQM Information Systems (F3) was positive and significant as hypothesized (β_3 = .741, t = 10.365). The TQM Information Systems factor includes and examines: the scope, validity, analysis, management, and use of data and information to drive quality excellence and improve competitive performance; and the adequacy of the company's data, information, and analysis to support improvement of the company's customer focus, products, services, and internal operations (MBNQA 1997). TQM Information Systems (F3) retained

two measures in the final TQM CFA measurement model: 1) Procedures have been developed for monitoring key indicators of plant performance (V19); and 2) Procedures have been developed for monitoring key indicators of customer satisfaction (V20).

Fundamental to TQM is collecting relevant information from an organization's operations and using it to monitor and improve quality. The importance of the expanded role of information and analysis in integrating information inside and outside the company (e.g., customers) has be identified in the literature through case studies (Willborn 1986; Riehl 1988). The importance of information in the development of TQM has also been noted by other researchers (Garvin 1983; Babbar 1992). This study provides empirical support for the use of information systems to help reinforce the implementation of TQM practices.

4.9.1.4 Hypothesis 4

The TQM (F9) to TQM Results (F4) structural path was positive and significant as hypothesized (β_4 = .157, t = 3.071). The TQM Results factor includes and examines: the company's performance and improvement in key business areas - product and service quality, productivity and operational effectiveness, and supply quality (MBNQA 1997). TQM Results (F4) retained seven measures: 1) After-sales customer complaints (V21); 2) Customer rejection of products (e.g., manufacturing defects) (V22); 3) Defect rates/cost (V23); 4) Employee absenteeism (V24); 5) Cost of quality (e.g., inspection and testing) (V25); 6) Employee grievances (V26); and 7) Total cost of purchased parts (V29).

TQM requires that companies monitor and improve their quality performance based on objective measures of quality and operational

results. Assuring customer-driven quality requires measurement of quality results. Researchers have suggested that quality performance is the result of understanding and measuring the factors that determine quality and product performance (Reddy and Berger 1983; Fortuin 1988; Cole 1990; Fisher 1992). This study empirically supports that measures should be developed and used to determine if the system is meeting the desired results.

4.9.1.5 Summary of Hypotheses 1-4

All of the structural paths from TQM to: TQM Strategic Systems (β_1 = 1.000), TQM Operational Systems (β_2 = .785, t = 12.856), TQM Information Systems (β_3 = .741, t = 10.365), and TQM Results (β_4 = .157, t = 3.071) were positive and significant as hypothesized (see Figure 4.1).

Nomological validity was assessed from the first-order TQM CFA measurement model using the inter-factor correlations (see Section 4.3.4). Nomological validity was confirmed when the correlations between the first-order factors (e.g., F1, F2, F3, and F4) were greater than zero. All correlations were statistically significant and positive; however, some of the correlations were very large (see Table 4.17). The large correlations among some of these first-order factors was not surprising since it was hypothesized a priori that these four underlying factors are associated with the higher-order factor of TQM. The lack of any negative correlations among the factors indicates that a high value on one factor does not preclude a high value on another factor. In other words, the factors compliment one another.

The higher-order TQM factor was hypothesized as accounting for or explaining all variance and covariance related to the first-order factors. The overall fit statistics of the second-order TQM CFA measurement model (see Table 4.19) were as good as the first-order model. This is as it should be, given that the second-order model merely specifies a higher-order order factor to account for the correlations among the lower-order factors, rather than of these factors among themselves, as was the case with the first-order structure. In other words, the covariation among the first-order factors is explained by their regression onto the higher-order factor of TQM. The empirical evidence supports that the presence of TQM Strategic Systems (F1), TQM Operational Systems (F2), TQM Information Systems (F3), and TQM Results (F4) encourages the emergence and acceptance of TQM (F9).

4.9.2 Hypotheses 5-8

In Section 2.8, parallels were drawn between TQM and ERM to show that the two concepts are so closely linked, that an operational framework of TQM could be adapted for ERM; therefore, an adaptation of the MBNQA framework was used as the operational framework of ERM. For example, ERM was operationalized using four multi-item scales corresponding to an adaptation of the four first-order factors associated with the MBNQA framework. It was subsequently hypothesized that the presence of ERM Strategic Systems (F5), ERM Operational Systems (F6), ERM Information Systems (F7), and ERM Results (F8) encourages the emergence and acceptance of ERM (F10); thus, β_5, β_6, β_7, and β_8 were proposed to be positive (see Figure 1.1). More specifically:

Hypothesis 5 (H5): $\beta_5 > 0$, $p < 0.05$
Hypothesis 6 (H6): $\beta_6 > 0$, $p < 0.05$
Hypothesis 7 (H7): $\beta_7 > 0$, $p < 0.05$

Hypothesis 8 (H8): $\beta_8 > 0$, $p < 0.05$

Each of these specific research hypotheses are now examined.

4.9.2.1 Hypothesis 5

The structural path from ERM (F10) to ERM Strategic Systems (F5) was positive as hypothesized ($\beta_5 = .939$). The ERM Strategic Systems factor includes issues pertaining to leadership, strategic planning, and customer/stakeholder focus. More specifically, an ERM Strategic System collectively examines: 1) how senior leaders guide the company in setting directions and in developing and sustaining ERM values; 2) how the company sets strategic directions and how it determines key action plans for ERM issues; and 3) how the company determines the environmental requirements and expectations of customers and stakeholders (McGee and Bhushman 1993; CGLI 1994; MBNQA 1997).

ERM Strategic Systems (F5) retained two measures in the final ERM CFA measurement model: 1) Environmental goals are clearly communicated to all plant personnel (V31); and 2) Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant (V32). Both of these remaining two measures include issues as they pertain to leadership, while the other measures associated with strategic planning and customer/stakeholder focus were dropped.

Leadership is defined as senior management's ability to create ERM values and in building these values into the way the organization operates (CGLI 1994). Leadership defines an organization's goals, expresses its commitment to protecting the environment, and provides the foundation on which ERM is developed. A common theme within the

literature is the importance of leadership in creating a culture for ERM in which the concept that waste and pollution are inevitable is purged (Bemowski 1991; McGee Bhushman 1993).

Research suggests, but does explicitly recognize, that the critical guide and motivator for ERM must come from senior management leadership (Arthur D. Little 1989; Hunt and Auster 1990; Schot 1991; Makower 1993, 1994; McGee and Bhushman 1993; Wever and Vorhaur 1993; CGLI 1994; Epstein 1996). This study provides empirical support for the need of senior management to become directly involved in ERM processes as a leader and role model.

4.9.2.2 Hypothesis 6

The structural path from ERM (F10) to ERM Operational Systems (F6) was positive and significant as hypothesized (β_6 = .769, t = 13.769). The ERM Operational Systems factor includes issues pertaining to human resource development and process management. More specifically, an ERM Operational System examines: 1) how the work force is enabled to develop and utilize its full potential, aligned with the company's ERM objectives; and 2) how key processes are designed, effectively managed, and improved to achieve higher ERM performance (McGee and Bhushman 1993; CGLI 1994; MBNQA 1997).

ERM Operational Systems (F6) retained two measures in the final ERM CFA measurement model: 1) An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant (V38); and 2) An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant (V39). Both of the remaining measures include issues as they

pertain to human resource development, while the other measures associated with process management were dropped.

Human resource development is defined as the success of an organization's efforts to realize the full potential of its workforce in implementing ERM (CGLI 1994). Human resource development examines the extent to which employees are educated, trained, and motivated to conduct their activities in an environmentally responsible manner. The employees must recognize the environmental responsibilities both for the company and themselves. Training can shape employees' positive attitudes about their company's commitment to ERM.

Many authors have used case studies and anecdotal examples to contend that ERM can only be achieved when there is a high level of commitment and involvement from people (Cook and Sethi 1991, 1992; Gripman 1991; Marguglio 1991; Cramer and Roes 1993; Wever and Vorhaur 1993; May and Flannery 1995; Gupta and Sharma 1996). This study provides empirical support that ERM demands that human resource development, in the form of training and development, assume strategic roles.

4.9.2.3 Hypothesis 7

The structural path from ERM (F10) to ERM Information Systems (F7) was positive and significant as hypothesized (β_7 = .654, t = 12.286). An ERM Information System was defined as the effectiveness of an organization's collection, analysis, and use of information for environmental planning and improvement (McGee and Bhushman 1993; CGLI 1994). ERM Information Systems (F7) retained two measures in the final ERM CFA measurement model: 1) Information about best-in-class

environmental performance is tracked and recorded by your plant (V44); and 2) Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis (V45).

Bracken (1985) suggested that formalized ERM programs require extensive information collection and analysis. By applying the tools of information planning to ERM, a company's information infrastructure can be aligned with strategic goals and business processes (Johannson 1993; Orlin, Swalwell, and Fitzgerald 1993). The importance of timely, reliable, and adequate information in ERM has been noted by several researchers; however, it has not been explicitly recognized. Fundamental to ERM is the selection, management, and use of comparative information to improve performance. This study supports that information and analysis on environmental best practices can help reinforce the implementation of ERM practices.

4.9.2.4 Hypothesis 8

The structural path from ERM (F10) to ERM Results (F8) was positive and significant as hypothesized (β_8 = .253, t = 4.736). ERM Results are defined as the organization's improvement's in ERM (McGee and Bhushman 1993; CGLI 1994). ERM Results (F8) retained four measures: 1) Volume of waste water discharges (V49); 2) Tons of solid waste landfilled (V50); 3) Tons of hazardous waste (V51); and 4) Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur dioxides, etc.) (V52). According to Wells, Hochman, and O'Connel (1994), ERM requires that organizations monitor and improve their environmental performance based on objective measures. This study provides empirical support that monitoring performance is integral to

ERM; meaning, measures should be identified and used to determine if the system is delivering the desired results.

4.9.2.5 Summary of Hypotheses 5-8

All of the structural paths from ERM to: ERM Strategic Systems (β_5 = .939), ERM Operational Systems (β_6 = .769, t = 13.769), ERM Information Systems (β_7 = .654, t = 12.286), and ERM Results (β_8 = .253, t = 4.736) were positive and significant as hypothesized (see Figure 4.1).

Nomological validity was assessed from the final first-order ERM CFA measurement model using the inter-factor correlations (see Section 4.3.4). Nomological validity was confirmed when the correlations between the first-order factors (e.g., F5, F6, F7, and F8) were greater than zero. All correlations were statistically significant and positive; however, some of the correlations were very large (see Table 4.18). The large correlations among some of these first-order factors was not surprising since it was hypothesized a priori that these four underlying factors are associated with the higher-order factor of ERM. The lack of any negative correlations among the factors indicates that a high value on one factor does not preclude a high value on another factor. In other words, the factors compliment one another.

The higher-order ERM factor was hypothesized as accounting for or explaining all variance and covariance related to the first-order factors. The overall fit statistics of the second-order ERM CFA measurement model (see Table 4.20) were as good as the first-order model. This is as it should be, given that the second-order model merely specifies a higher-order order factor to account for the

correlations among the lower-order factors, rather than of these factors among themselves, as was the case with the first-order structures. In other words, the covariation among the first-order factors is explained by their regression onto the higher-order factor of ERM. The empirical evidence supports that the presence of ERM Strategic Systems (F5), ERM Operational Systems (F6), ERM Information Systems (F7), and ERM Results (F8) encourages the emergence and acceptance of ERM (F10).

4.9.3 Hypothesis 9

It was hypothesized that the presence of a TQM based system encourages the emergence and acceptance of an ERM based system; thus, γ_1 was hypothesized as being positive and significant. More specifically:

Hypothesis 9 (H9): $\gamma_1 > 0$, $p < 0.05$

The empirical results suggest that firms with advanced TQM systems in place also have more advanced ERM systems than firms just initiating TQM ($\gamma_1 = .484$, $t = 8.486$). In other words, ERM based systems will be stronger in firms as TQM based systems become more developed. Hence, the results support the TQM-to-ERM link.

4.9.4 Hypotheses 10-13

This dissertation was primarily interested in determining the presence of a relationship between TQM and ERM systems. However, in addition, this dissertation was also interested in exploring the similarities and differences between the structures of these systems. There was no reason, a priori, to believe that the structures associated with TQM and ERM based systems would be different. Therefore, the

structures between TQM and ERM based systems were hypothesized to be similar or parallel one another. More specifically:

Hypothesis 10 (H10): $\beta_1 - \beta_5 = 0$, $p < 0.05$
Hypothesis 11 (H11): $\beta_2 - \beta_6 = 0$, $p < 0.05$
Hypothesis 12 (H12): $\beta_3 - \beta_7 = 0$, $p < 0.05$
Hypothesis 13 (H13): $\beta_4 - \beta_8 = 0$, $p < 0.05$

Turning to the univariate LM χ^2 statistics and related probability values associated with each equality constraint, it was shown that only the fourth constraint was invariant across both TQM and ERM based systems (see Section 4.7). The univariate and multivariate analyses for the first three constraints reflected the noninvariance of the corresponding structural paths across the TQM and ERM based systems. However, turning to the univariate LM χ^2 statistics and related probability values for each equality constraint, provides an extremely rigorous assessment of invariance.

A re-examination of Figure 4.1 can provide additional insights regarding whether the structures parallel one another. Notice that the structural coefficients which parallel one another in the TQM and ERM based systems are very similar in magnitude. For example, TQM Strategic Systems (F1) ($\beta_1 = 1.000$) and ERM Strategic Systems (F5) ($\beta_5 = .939$). Even though the univariate and multivariate analyses reflected noninvariance, these structural paths appear to parallel one another in magnitude. Similarly, TQM Operational Systems (F2) ($\beta_2 = .785$) and ERM Operational Systems (F6) ($\beta_6 = .769$), and TQM Information Systems (F3) ($\beta_3 = .741$) and ERM Information Systems (F7) ($\beta_7 = .654$), appear to parallel one another in magnitude, even though the univariate and multivariate analyses reflected noninvariance. Statistically, it was

shown that only the fourth parallel structures, TQM Results (F4) and ERM Results (F5), were invariant across both TQM and ERM based systems.

4.10 Summary

In summary, all of the causal paths specified in the hypothesized model (Figure 1.1) were found to be positive and statistically significant. These paths reflected the impact of: 1) TQM (F9) on TQM Strategic Systems (F1), TQM Operational Systems (F2), TQM Information Systems (F3), and TQM Results (F4); 2) ERM (F10) on ERM Strategic Systems (F5), ERM Operational Systems (F6), ERM Information Systems (F7), and ERM Results (F8); and 3) TQM (F9) on ERM (F10). In other words, all of the structural paths from TQM to: TQM Strategic Systems (β_1 = 1.000), TQM Operational Systems (β_2 = .785, t = 12.856), TQM Information Systems (β_3 = .741, t = 10.365), and TQM Results (β_4 = .157, t = 3.071) were positive and significant as hypothesized. All of the structural paths from ERM to: ERM Strategic Systems (β_5 = .939), ERM Operational Systems (β_6 = .769, t = 13.769), ERM Information Systems (β_7 = .654, t = 12.286). and ERM Results (β_8 = .253, t = 4.736) were positive and significant as hypothesized. The structural path from TQM to ERM (γ_1 = .484, t = 8.486) was also positive and significant as hypothesized. Paths not specified a priori did not prove to be essential components of the causal structure; therefore, they were not added to the model. No paths were found to be misspecified. Also, none of the hypothesized paths were nonsignificant and were subsequently left in the model.

It was also shown that only the fourth constraint or parallel structures, TQM Results (F9) and ERM Results (F10) were invariant across

both TQM and ERM based systems. The univariate and multivariate analyses for the first three constraints (TQM/ERM Strategic Systems, TQM/ERM Operational Systems, TQM/ERM Information Systems) reflected the noninvariance of the structural paths across the TQM and ERM based systems. However, turning to these univariate LM χ^2 statistics and related probability values for each equality constraint provides an extremely rigorous assessment of invariance. Notice that the structural coefficients which parallel one another in the TQM and ERM based systems are very similar in magnitude (see Figure 4.1). Chapter 5 will now build on the findings and analysis of this chapter by discussing the results.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Overview and Chapter Contents

Chapter 5 builds on the findings and analysis of the previous chapter by discussing the results and using them to act as a basis for future research. The first section (5.2) of this chapter assesses the contribution of the research from a managerial (5.2.1) and academic (5.2.2) perspective. The first subsection (5.2.1) touches on the managerial contributions of the dissertation by focusing on the primary research questions of the dissertation: 1) Is there a relationship between TQM and ERM based systems (5.2.1.1)?; and, 2) If there is a relationship present between TQM and ERM, then what is the nature of the relationship (5.2.1.2)? The final subsection (5.2.2) touches on several of the academic contributions of the research: 1) the development and validation of manifest variables and measures; 2) the development and assessment of constructs; and 3) the development and assessment of a theoretical structure (model) that forms the TQM-to-ERM link. The next section (5.3) examines some of the limitations of the research. Finally, the fifth section (5.4) looks at future research possibilities that arise as a result of this study.

5.2 Assessing the Contributions of the Research

5.2.1 Managerial Contributions

5.2.1.1 The Relationship Between TQM and ERM

Ferdows and DeMeyer (1990) showed that quality management practices are associated with improvements in the largest number of performance indicators - not only those related to quality itself, but also those related to dependability, flexibility, and cost. Quality

management practices positively impacted all four capabilities and were the only management practices that impacted other capabilities. These researchers challenged the longheld assumption that achieving strength along one capability should come at the expense of the rest. This pattern of cumulative returns has been referred to as the "sandcone model."

Since TQM is regarded as an integrated set of quality management practices (Ross 1993), TQM itself can be a stepping stone to building cumulative capabilities. Leading practitioners of TQM, such as Motorola and Xerox, have demonstrated cumulative returns along capabilities in terms of quality, dependability, flexibility, and cost. Recognizing its cumulative building capabilities, practitioners of TQM have been able to use it as a foundation for major developments such as Time-Based Competition (TBC) and Mass Customization (Blackburn 1991; Carter and Melnyk 1992; Pine 1993).

A similar relationship between TQM and ERM has been suggested. There has been a great deal of discussion within the literature about TQM in environmental programs. It has been suggested by several researchers, through mostly conceptual analyses and case studies, that significant benefits arise from applying what has been learned about TQM to ERM (Habicht 1991; Alm 1992; Friedman 1992; Rappaport 1992; Welford 1992; Wheeler 1992; Green 1993; Klassen and McLaughlin 1993; Makower 1993; Neidart 1993; Thompson and Rauck 1993; Woods 1993; Willig 1994; Hanna and Newman 1995; Hart 1995; May and Flannery 1995; McInerney and White 1995; Sarkis and Rasheed 1995; Shrivastava 1995a; Epstein 1996; Puri 1996; Rodinelli and Berry 1997). In these studies, the authors describe how the implementation of ERM can be made more

successful by integrating it into a TQM system. In other words, the ability to reframe learnings from TQM is crucial to ERM.

For example, Klassen and McLaughlin (1993) suggested the need for an empirical investigation which examines whether firms which have advanced TQM programs in place also have advanced environmental management programs in place than firms just initiating TQM. A case study analysis by Post and Altman (1992) identified that a firm's ability to reframe learnings from quality management programs is crucial to being environmentally responsible. Some researchers, such as Makower (1993) and Willig (1994), bring together first hand reports on how leading companies are going beyond meeting regulatory compliance to gaining a competitive advantage and improved profitability by applying TQM practices to ERM.

All of these examples assume there is a relationship between TQM and ERM. The normative literature and case studies which predominates the ERM field, suggests, but does not explicitly recognize, that in TQM there is an explainable, understandable, and documental path to ERM. Such postulated associations between TQM and ERM are based on deductive reasoning and case analysis. Unfortunately, while case studies and deductive arguments have emphasized the virtues of TQM's role in ERM, researchers have not supported these arguments with extensive systematic empirical analyses.

Research directed at developing a rationally consistent theory of ERM which can be consistently related to management theories such as TQM represented an unexplored proposition. The overarching goal of this dissertation was to investigate the theoretical linkage between TQM and ERM by answering the following research question:

Is there a relationship between TQM and ERM based systems?
It was hypothesized that the presence of a TQM based system encourages the emergence and acceptance of an ERM based system. The empirical results of this dissertation support the TQM-to-ERM link. The results suggest that firms with advanced TQM systems in place also have more advanced ERM systems than firms just initiating TQM. In other words, ERM based systems will be stronger in firms as TQM based systems become more developed.

What is being argued with these results is that TQM systems condition firms to be more interested in the need for an ERM system. When a TQM system precedes ERM, it increases the probability of an ERM system being present. The systematic view of TQM, encompassing both the finished product or service and all the supporting activities to provide them, provides a strong rational for an explicit focus on ERM. Although originally applied to operations management for the purpose of improving product quality (i.e., reducing product waste in time, materials, and labor), the concept of TQM can be translated to the realm of ERM.

For example, companies can utilize TQM approaches to developing a system-wide and integrated approach to the reduction and elimination of all waste streams associated with the design, manufacture, use, and/or disposal of products and materials. Relevant TQM principles which can be integrated into waste minimization programs include: 1) a systems analysis process orientation that aims to reduce inefficiencies and identify product problems; 2) data-driven tools, such as cause and effect diagrams, quality evolution charts, pareto analysis, and control charts; and, 3) a team orientation that uses the knowledge of employees to develop solutions for waste problems.

For example, based on 8 detailed case studies of Dutch companies, Cramer and Roes (1993) showed that employee involvement can be promoted by improving employee-management interaction and promoting responsibility for the environment among all levels of management including individual employees. A team orientation which used the knowledge of employees to develop solutions for waste problems was a relevant TQM principle that was integrated into ERM. Using such a team orientation for ERM has also been advocated by a number of groups, most notably the Global Environmental Management Initiative (GEMI) and the Council on Environmental Quality.

GEMI (1993) also cites a member company facility that uses quality tools to discover opportunities for pollution prevention and to measure the effectiveness of improvements made. The facility, whose environmental managers complained that soil contamination analyses were taking too long to complete, assembled a team to: 1) arrive at a specification for turnaround time; and, 2) analyze the reasons for existing turnaround time. The team first agreed on the major causes of the delayed turnaround time; then, they constructed a diagram that listed the detailed causes contributing to each major factor. The same facility proceeded to make use of pareto charts which is a graphic tool that organizes data to identify and focus on major problems. A pareto chart takes data on a situation or process, ranks it in order, and thus focuses attention on opportunities to maximize improvement. The team working on the soil contamination analyses delays organized the data relating to the causes of those delays into a pareto chart that showed 80 percent of the turnaround delay could be attributed to two factors: 1) a lack of communication between divisions within the company to

anticipate information needs; and, 2) a lack of a standard analytic format for lab technicians. Shortly after beginning their improvement process, the soil contamination analyses team used a histogram to measure how close they were to achieving their time-reduction goal. The histogram showed that they had reduced the mean delivery time from 56 to 31 days and the dispersion had decreased from 64 to 37 percent.

3M and AT&T are also excellent examples of companies which were among the first to extend their TQM initiatives to ERM (Shedroff and Bitters 1991; Thompson and Rauck 1993; Sandelands 1994). These companies utilized TQM approaches to work towards a goal of zero waste discharges. TQM principles which were integrated into their waste minimization programs included the use of pareto analysis and control charts to signal pollution problems with the manufacturing process. For example, control charts were used to determine the capability of a wastewater treatment system to operate within permit limits. Each company now reports aggregate savings and significant environmental benefits generated by using TQM concepts in environmental management.

Proctor & Gamble has used benchmarking techniques to assess conformance with elements of its own environmental management system. The company regularly audits its facilities throughout the world in the areas of government and public relations, people capability, direct environmental impact, incident prevention, and continuous improvement. Standards in each of these areas are developed at the facility level ensuring business unit commitment and support, and a score is generated for each facility.

Sonoco's experience with materials reclamation illustrates how it used quality management principles to integrate environmental objectives

(Rondinelli and Berry 1997). Sonoco's success with materials reclamation resulted mainly from the corporation's quality-based culture. A strong and consistent vision from top leadership of the company was essential for environmental management. This was reflected by the chairman's "if we make it, we take it back" pronouncement. His clear environmental vision laid out an objective that each division and the corporation as a whole could strive to attain. The quality-based principles also encouraged managers to seek solutions with multiple benefits. Division managers realized that interdivisional cooperation and cross-functional communication could lead to economies and opportunities both for them and for Sonoco.

By using these TQM tools, methods, and practices to minimize waste, a firm can reduce disposal costs and permit requirements, avoid environmental fines, boost profits, discover new business opportunities, rejuvenate employee morale, and protect and improve the state of the environment. From an operations management perspective, simultaneous cost reduction and waste reduction can be demonstrated throughout process in areas encompassing shipping and distribution costs, raw material costs, actual manufacturing and processing costs, packaging costs, costs of treatment or disposal of process emissions, landfill use costs, and customer disposal costs.

5.2.1.2 The Nature of the Relationship Between TQM and ERM

The overarching goal of this dissertation was to investigate the theoretical linkage between TQM and ERM via a structural equation model by answering the following research questions:

1. Is there a relationship between TQM and ERM (this question was discussed in the previous section)?

2. If there is a relationship present between TQM and ERM, then what is the nature of the relationship?

These questions collectively reflect an interesting premise. Namely, ERM systems are viewed as being TQM systems modified to deal with environmental issues. The gradual evolution of quality to include aspects of the environment has been anticipated by several authors (Mizuno 1988; May and Flannery 1995; Sarkis and Rasheed 1995; Epstein 1996). The "no waste" aim of ERM based systems closely parallels the TQM goal of "zero defects." TQM focuses on waste as it applies to process inefficiencies, whereas ERM tends to focus more on concrete outputs, such as solid and hazardous waste. Because the two concepts share a similar focus, it makes sense to use many of the tools, methods, and practices of TQM in implementing an ERM based system. Given this perspective, the structure of ERM systems was expected to parallel or be very similar to that found in TQM systems.

There was no reason, a priori, to believe that the structures associated with TQM and ERM based systems would be different. Therefore, the parallel structures between TQM and ERM based systems were hypothesized to be similar to one another in magnitude. The structural coefficients which paralleled one another in the TQM and ERM based systems were very similar in magnitude. Even though the univariate and multivariate analyses reflected noninvariance for three parts of the structure (e.g., Strategic Systems, Operational Systems, Information Systems), all parallel structural paths were close in magnitude. These results suggest that TQM can serve as a ready bridge for an ERM based system.

The results of this dissertation clarifies much of the confusion surrounding the relationship between TQM and ERM. It does so by pointing to the potential synergies between TQM and ERM. Meaning, firms which have developed capabilities in TQM will be more likely to develop the capabilities necessary for being environmentally responsible. Furthermore, they will be able to develop the capabilities for being environmentally responsible more quickly than firms without a TQM based system because they will be able to reframe their learnings from existing quality tools, methods, and practices.

This dissertation has developed an integrated theory about how TQM based capabilities can be leveraged for ERM. It suggests that efforts should be coordinated to take advantage of the potential synergies between TQM and ERM. The means for capturing these synergies can be accomplished by using the MBNQA framework. Eastman Kodak, a former recipient of the MBNQA, has already begun to apply the principles of TQM to its environmental management program (CGLI 1994). Remember, the TQM measurement model was operationalized using a set of four multi-item scales corresponding to the four factors of the MBNQA framework. Likewise, ERM was operationalized in terms of the four first-order factors described by the MBNQA framework. The MBNQA framework was adapted to address environmental issues and furthermore, it was shown that the framework can be used as a basis for an integrative definition of ERM. The four-factor structures (e.g., Strategic Systems, Operational Systems, Information Systems, Results) of the initially hypothesized TQM and ERM CFA measurement models were retained in the final models. In other words, the TQM constructs were indeed good predictors of the ERM constructs. This adaptation of the MBNQA

framework suggests that quality principles can be seamlessly integrated into the practice of managing environmental issues.

5.2.1.3 Other Managerial Contributions

The four first-order factors for TQM and ERM each can form the basis of a preliminary multidimensional measure or index of TQM and ERM. Computing an overall index for TQM or ERM might be premature. There are numerous unresolved theoretical issues, such as whether the dimensions are compensatory in nature (Kerlinger 1964), and methodological issues, such as whether to use linear models. However, until the construct measures are replicated, any overall index that is computed for TQM and ERM will have limited managerial contributions. It would be reasonable to compute an overall score for each dimension, since they are unidimensional. A simple sum of item scores would be adequate because the results are generally comparable with those obtained by a more rigorous utilization of factor score regressions. Such an aggregation could have many practical benefits for managers.

A profile along the four first-order factors would be useful to practitioners for demonstrating the benefits of an existing TQM or ERM based system. Another use could be an evaluation of competitors' applications of TQM or ERM. An assessment of a competing system based on the four first-order factors could reveal the reasons for their success. The results could form the basis for new TQM or ERM based systems and enhancements to old or current systems. The measures of the TQM and ERM factors may also constitute the dependent variables in empirical studies concerning TQM and ERM. While this effort will not eliminate the lack of consensus in the field regarding the appropriate

dependent variable and how to measure them, it is a constructive move in that direction.

5.2.2 Academic Contribution

Often in the search for substantive relationships, an emerging field tends to overlook methodological issues such as measurement (Venkatraman and Grant 1986; Sethi and King 1994). The TQM field has started to pay greater attention to such issues (Saraph, Benson, and Schroeder 1989; Flynn, Schroeder, and Sakakibara 1994; Ahire, Golhar, and Waller 1996). However, this was prompted by a retrospective look in which substantive results were rendered inconsequential because of poorly developed measures. This study has made an attempt to preclude such a situation in the area of ERM. The field is still emerging and has made no attempts to develop and validate an instrument for measuring ERM. One of the primary academic contributions of this study has been the development and validation of instruments for measuring TQM and ERM which in turn provides the underpinnings for a program of research in both areas.

Given that reliable and valid measures were needed for both TQM and ERM constructs, which are in turn important for theory building, this dissertation has developed and validated appropriate measurement instruments for the two concepts. Schwab (1980) differentiated between two interrelated streams of research: 1) substantive; and 2) measurement. Studies belonging to the substantive stream examine the nature of theoretical relationships between independent and dependent variables. Research in the measurement stream includes the development and validation of instruments designed to measure constructs for use in subsequent theoretical models. Even though measurement properties are

important, most TQM and ERM studies are substantive in nature. The growth of interest in understanding relationships between variables that cannot be directly observed, however, makes the measurement issue more important than ever. Without a proper methodology to assess the validity of measurement instruments, the degree of confidence in substantive theory building and research findings is and will continue to be doubtful.

Bagozzi, Yi, and Phillips (1991) broadly classified approaches to instrument validation into two categories: 1) classical; and 2) contemporary. The classical approach uses techniques including Campbell and Fiske's (1959) multitrait-multimethod (MTMM) analysis and exploratory factor analysis (EFA). Despite their popularity in research, several researchers (Segars and Grover 1993; Subramanian and Nilakanta 1994) criticized the use of these techniques for instrument validation. For example, as for EFA, Segars and Grover (1993) discussed a number of shortcomings in using EFA to test for convergent and discriminant validity and to search for theoretical constructs. First, EFA models do not provide any explicit test statistics for assessing convergent and discriminant validity. Second, since the model searches for factors in an exploratory manner and each item is expressed as a function of all possible factors, the estimates obtained for factor loadings are not unique and the factor solution obtained is just one of an infinite number of possible solutions. In addition, Subramanian and Nilakanta (1994) pointed out that the criteria used to eliminate or retain factors in the final solution were rather arbitrary, leading to a tendency to either "overfactor" or "underfactor" a construct.

To overcome these weaknesses, a newer approach, namely structural equation modeling (SEM) was used in this study. This approach provided a more rigorous validation of instruments for unobserved constructs and test of the research model than the classical approach (e.g., EFA). The ability of SEM to assess relationships comprehensively has provided a transition from exploratory to confirmatory analysis (Bollen 1989). This dissertation has illustrated how this approach can be used to test instrument validation and modify instruments for better psychometric properties.

The relationship between TQM and ERM has been examined within the literature with ERM theory far from being fully developed (Post and Altman 1992; Klassen 1992). As was presented in Chapter 2, the ERM literature suffers from a lack of: 1) systematic scale development; 2) content validity; and 3) empirical validation. In Section 2.8, parallels were drawn between TQM and ERM to show that the two concepts were so closely linked, that an operational framework of TQM could be adapted for ERM. Therefore, an adaptation of the operational framework of TQM was used as the framework for ERM. For example, ERM was operationalized using four multi-item scales corresponding to an adaptation of the four categories associated with the operational framework for TQM (see Section 3.4). The expected scholarly contribution of this dissertation, in addition to investigating the theoretical linkage between TQM and ERM and the nature of this relationship, was to help build ERM theory by answering the following ancillary research question:

Are the TQM constructs good predictors for the ERM constructs?

The TQM measurement model was operationalized using a set of four multi-item scales corresponding to the four factors of the MBNQA framework: 1) TQM Strategic Systems; 2) TQM Operational Systems; 3) TQM Information Systems; and TQM Results. The ERM construct was conceptualized in terms of the four first-order factors described by the MBNQA framework: 1) ERM Strategic Systems; 2) ERM Operational Systems; 3) ERM Information Systems; and 4) ERM Results. Multi-item scales also served as parsimonious representations of unidimensional constructs.

Both the TQM and ERM measurement models were tested using CFA before assessing the structural relationships shown in Figure 1.1. After eliminating items that had low item-factor loadings and/or loaded on multiple factors, the Bentler-Bonett Normed Fit Index (NFI), Bentler-Bonett Non-Normed Fit Index (NNFI), and Comparative Fit Index (CFI) were iteratively used to determine whether the CFA measurement models fitted the data well. First, to make certain that a given item represented the construct underlying each factor, a loading of 0.50 was used as the minimum cutoff. Second, to avoid problems with cross-loadings, the Lagrangian Multiplier (LM) test was used to identify significant cross-loadings (i.e., a loading on more than one factor). As recommended, only one parameter was changed at every step (Joreskog and Sorbom 1993).

Model modifications were continued until all parameter estimates and overall fit measures were judged to be statistically and substantively satisfactory. The revised and final full first-order TQM and ERM CFA models, consisting of 13 and 10 measures, respectively, were re-estimated (see Tables 4.13 and 4.14). The four-factor structure of the initially hypothesized TQM and ERM CFA measurement models were retained in the final models. The fit of the models were satisfactory

based on all the key measurement criteria (e.g., χ^2, χ^2/df, NFI, NNFI, and CFI). In fact, the ERM model fitted the data better than the TQM model. For example, the ERM CFA measurement model had a CFI of 0.991 while the CFI for the TQM CFA measurement model was 0.939. Furthermore, the sign and significance of the item loadings, along with an assessment of reliability indices for each factor using Cronbach's alpha also supported the satisfactory fit of the models to the data (see Tables 4.15 and 4.16). These results conclusively establish that the TQM constructs are good predictors for the ERM constructs.

Furthermore, while much of the TQM and ERM literature uses univariate or bivariate techniques, this dissertation has advanced methodology by performing structural equation modeling. A structural equation model was designed to test whether the theoretical model, which was developed on case studies and theory, could be rejected. The modeling approach used in this dissertation to investigate the theoretical linkage between TQM and ERM was more quantitatively sophisticated than techniques typically used in the literature. Typically, research emphasis has progressed from theory building to theory testing, from qualitative to quantitative methods. While the ERM literature evolved somewhat in this matter, there has been too much reliance on descriptive research (Hanna and Newman 1995; Klassen 1995). Although less quantitative methods continue to offer richness, the structural equation model used in this dissertation offers increased internal validity.

ERM theory building required a foreword and comprehensive outlook in which the theoretical constructs of ERM were developed and validated.

The advancement of the ERM field depends on giving this type of priority to measurement. This is because theory construction and cumulative tradition, the ultimate objectives of any field, are inseparable from measurement (Bagozzi 1982). This dissertation has moved from anecdotes and case studies to a testable model and specific research hypotheses, linking the theoretical concept of ERM to empirical indicants. In search for substantive relationships, the ERM field has overlooked the methodological issues such as measurement. This dissertation has contributed to ERM theory building by identifying the constructs associated with ERM, developing scales for measuring these constructs, and empirically validating the scales.

5.3 Limitations of the Research

The results support the specific research hypotheses proposed in Chapter 1. However, there are limitations to the research. This section will examine those limitations in the context of their impact on the generalizability of the results.

A limitation to the structural equation modeling methodology is that it can only serve to disconfirm a model, not prove it (Handfield and Ghosh 1997). In other words, the use of the SEM in Figure 1.1 was designed to only test whether the theoretical model could be rejected. However, an advantage to this method was that: 1) it provides a straightforward way of dealing with multiple relationships simultaneously while providing statistical efficiency; 2) its ability to assess the relationships comprehensively has provided a transition from exploratory to confirmatory analysis; and 3) its ability to represent unobserved concepts in these relationships and account for measurement error in the estimation process.

A second concern was that using self report data from one source opens the data to contamination from correlations among variables. However, sometimes key informants provide the only avenue for information desired (Huber and Power 1985), and the practical utility of same source self-reports makes them virtually indispensable in many research contexts (Podsakoff and Organ 1986; Parkhe 1993). Phillips (1981) indicated that high ranking informants tend to be more reliable sources of information than their lower ranking counterparts; therefore, a high response rate from plant managers was an optimal outcome.

A third concern was that although self-assessment measures are prone to potential bias, they are the most commonly used method in empirical research. A major advantage of using the perceived measurement scales is that it permits comparisons across plants, based on each individual manager's assessments within their own particular cultures, time horizons, economic conditions, and expectations. Consistent with the research design in this study, this scale captured the perceptions of the respondents that underlied their decisions, and was easy and natural for respondents to use. Based on extensive pretests of the measurement instrument, the research was designed to limit the possibility of halo effects and socially desirable answers.

A fourth concern deals with "omitted" firm variable bias. One might omit variables which significantly bias results and interpretation (Boulding and Staelin 1990, 1995; Calantone, Schmidt, and Song 1996). Thus, there is a hidden threat to the validity of the results in this context. An important criterion to be "not wrong" is whether an alternative explanation that firm level effects are operating as an

invisible hand can be defeated. There exists the possibility that the omitted firm variables bias the effect on performance and, indeed, even the intermediate effects in cross-sectional studies such as this. While the test of the theta-delta matrix of each CFA measurement model pointed to the lack of omitted variable bias (see Section 4.8), this has been attributed by some authors to the absence of common method bias in measurement (Calantone, Schmidt, and Song 1996). Thus, no definitive defense is available from that test alone. The challenge for a cross-sectional study such as this is to reject the hypothesis that many of the parameters associated with the dependent variables are biased by "omitted" firm level effects. Since only one observation was collected per plant in the sample, an examination of whether bias exists due to omitted firm effects is not possible.

While this dissertation tested if the model was consistent with the data, it was not able to establish causality, only association. While the directionality of the relationship was established theoretically, it is possible to argue that the directionality of the specific research hypothesis could be reversed in some instances. For example, a causal relationship could be posed depicting TQM from ERM; however, there was no support in the literature for this relationship. The results would be grossly misleading because there is a conceptual flaw in the reversed relationship. The TQM-to-ERM link forms the proposed relationship for the theoretical model. Ideally, one needs to collect time-series data in the form of a longitudinal study to test causal relationships. This cannot be accomplished in a cross-sectional study which only captures the data in snapshot of time.

The final concern pertains to external validity which is the ability to generalize results beyond the present study. The major drawback of this single industry study is its lack of external validity. External validity is more easily achieved in cross-industry studies. However, a comparative profile of the plants across SIC 3714 within the automotive industry highlights the diversity of the products manufactured. Plants in the sample ranged from manufacturers of entire seating systems to manufacturers of anti-lock braking systems. Thus, the external validity of the results are not as severely compromised by this single industry as it would be if a more homogenous industry group was used. Hence, the findings of this study should have a much wider appeal than is typically associated with single-industry studies. Of course, external validity is never completely achieved through even cross-industry studies. External validity requires a series of different studies which substantiate and complement one another.

5.4 Future Research

The TQM and ERM measures were a preliminary attempt at operationalizing these higher-order concepts and must therefore be replicated and refined. Alternative measures must be formulated and compared with the results of this study to clarify the theoretical foundations of these higher-order constructs. Also, the structural equation model developed requires validation on another data set. This is particularly critical because the model was developed as well as tested using the same data set. Additionally, given the perceptual nature of the data used to reflect the theoretical constructs, it is important to recognize the problems associated with the "key informant" approach (Phillips 1981; Huber and Power 1985; Sethi and King 1994).

Thus, a logical extension would be to use multiple informants to verify perceptions regarding the features and impact of TQM and ERM based systems.

Beyond these fairly immediate suggestions for future research, the research model should be used in an international setting. With the global interest in both quality and environmental management practices, the TQM-to-ERM link is potentially well suited and adaptable enough to use in testing international applications. Of course, any attempt to do so would have to be accompanied by rigorous and thorough construct evaluation. Cultural differences could easily lead to false findings if the proper preparatory work is not first performed in the international setting.

Furthermore, since over 80% of the people employed in the U.S. are employed in services, it would not make sense to confine TQM and ERM research to the manufacturing sector of the economy, especially since the service sector also has to deal with both quality and environmental issues. To do this, future research will need to recognize how service businesses are similar and different from manufacturing businesses in terms of quality and environmental management. This translation of manufacturing TQM and ERM based systems to service organizations cannot be presumed and would have to be carefully thought out.

The exact structure of TQM and ERM must also be explored in more detail. An explicit consideration of the causal relationships among the first-order factors will be necessary. No research to date has provided empirical evidence of the linkages between implementation of TQM and ERM criteria. An explicit model is required in establishing the relationships which exist between the various criteria (e.g., Strategic

Systems, Operational Systems, Information Systems, and Results). This type of study should provide a framework that enables researchers and managers to gain improved insight into TQM and ERM by providing a generic framework for implementation. Even though some managers embrace the concepts of TQM and ERM without understanding its short- and long-term impact or the extent of commitment required at all levels, the key elements which lead to successful TQM and ERM based systems in organizations are not well understood. Managers need a methodology for discovering solutions that yield the greatest benefits and they need specific guidance on implementation issues which are generalizable between firms. While many firms have adopted some form of TQM and ERM, their implementation has not been equally successful (Bowles and Hammond 1991; Walley and Whitehead 1994).

The reasons for implementation failure are not well understood. However, unfocused efforts may lead to failed TQM and ERM based systems. Although the literature has failed to examine linkages among the various constructs and their impact on performance, several elements of both TQM and ERM systems have emerged from reported conceptual papers, case studies, and empirical research. For example, management leadership, written policy, and long-term planning are among the most commonly implemented elements of both TQM and ERM based systems (Makower 1993; Epstein 1996). However, due to the paucity of insights into the interactions among these various elements, organizations employ them in isolation. In other words, TQM and ERM are being implemented in piecemeal fashions. A majority of the research has provided managers with normative prescriptions and managerial guidelines, but it has failed to address how to develop and successfully implement TQM and ERM.

Managers need frameworks or guidelines which they can use to better understand what ERM is and its components. However, a great deal of the information surrounding ERM is either legally based or derived from anecdotal stories and case studies (Piet 1994; Danesi 1996). An empirical test of the linkages between the TQM and ERM factors can help to provide a roadmap for firms seeking to progress towards total quality and environmentally responsible cultures.

Other future topics might consider the differences in performance when viewing the activities from a compliance as compared to a leadership perspective. Here, the interest would be in determining if the structure of the ERM system is influenced by the orientation or extent of leadership of the organization when it comes to ERM. In addition, it would be interesting to determine if the structure is unchanged by the presence of other strategic initiatives such as Just In Time or Time Based Competition. Also, it might be worthwhile to explicitly consider exploring the benefits of ERM projects (and the factors that affect these benefits). Finally, a comparison of the structures of ERM under ISO 14000 settings versus non-ISO 14000 settings might be insightful. Along the same lines, it would be interesting to see factor score profiles of companies conditioned on ISO/QS 9000 certification, union representation, and size.

It would be expected that more managers be interested in the implementation and use of ERM based systems. After all, ERM involves the identification and elimination of in-process waste streams. However, for most firms, ERM has not achieved the same degree of acceptance as have JIT, TQM, and TBC (Makower 1993, 1994; Epstein 1996). In practice, most firms are unable to justify the assumption of

a leadership role when it comes to ERM. Leadership responses would include focusing on the firm's processes to see whether they might be made environmentally safer, rather than just on problems as they occur; or considering societal needs that go beyond existing legislation and regulation (Eckel, Fisher, and Russell 1992). If successful, this approach can help put the firm in position where it can help to dictate regulations and standards rather than be influenced by them.

However, for most companies, compliance is seen as an adequate position to assume (Bavaria 1996; Epstein 1996). With compliance, the firm does only what is necessary to meet the letter of the law. It is a reactive position which means environmental problems are corrected once they have been created. This is relatively ineffective because it does not attack the causal factors, merely the symptoms (Carpenter 1991). It is also a potentially dangerous position given the retroactive and dynamic nature of many laws. That is, what may be in compliance today may be considered to be out-of-compliance tomorrow. As a result, the firm may find itself always spending to bring itself into compliance with regulations that are continuously becoming more stringent.

The challenge of determining whether it is better for the firm to simply emphasize compliance or whether the firm wants to become recognized as an industrial leader in the development and application of ERM based systems describes the first of many obstacles and paradoxes surrounding ERM. In large part, the failure of management to become more environmentally responsible is really a reflection of its inability to address and resolve these paradoxes and problems. The following are some of the most important paradoxes and problems associated with the development and implementation of ERM based systems:

- Top management must be willing to accept and champion corporate-wide developments if ERM is to become widespread (Hunt and Auster 1990; Schot 1991; Epstein 1996). However, when dealing with ERM, there is a strong bias in favor of ignorance at the highest levels of the firm (Melnyk 1995).

- In the short run, implementing ERM often causes costs to rise (Palmer, Oates, and Portney 1995). However, there is a real concern as to whether customers are willing to pay the added costs associated with having something that is environmentally friendly (Rosewicz 1990).

- It has been argued that being environmentally responsible ultimately makes a company more efficient and more competitive (Royston 1980; Bonifant 1994a, 1994b; Bonifant and Ratcliff 1994; Van der Linde 1995a, 1995b, 1995c). However, there are many reported cases of ERM investments which have resulted in negative returns (Jaffe, Peterson, Portney, and Stavins 1993, 1994; Walley and Whitehead 1994).

- Ideally, the most appropriate place for considering ERM issues is in the design phase since the amount of waste generated is a direct consequence of decisions made during design (Bowman 1996; Fiskel 1993, 1996). However, there is a lack of appropriate measures and tools for capturing the environmental impact of designs (Van Weenen and Eeckles 1989; Allenby 1993; Graedel and Allenby 1995).

- Managers need frameworks or guidelines which they can use to better understand what ERM is and its components. However, a great deal of the information surrounding ERM is either legally-based or derived from anecdotal stories and case studies (Piet 1994; Danesi 1996).

- Managers have difficulty assessing the impact of ERM programs because of the lack of appropriate measures. In order for ERM to be given serious consideration by a firm, a process is required for evaluating ERM by appropriately including environmental costs and savings for each investment option (Sarkis and Rasheed 1995; Epstein 1996).

It is these paradoxes and problems which should encourage future research in ERM. Management's ability to become more environmentally responsible will depend on the ability of future research to address and ultimately resolve these paradoxes and problems. Once resolved, it would be expected that more managers be interested in the implementation and use of ERM based systems. The intent of this last chapter was to build on the findings and analysis of the previous chapter by discussing the results and using them to act as a basis for future research. This

chapter should not be viewed as an ending but rather as a start. In this case, the start is future research.

5.5 Concluding Comments

Research directed at developing a rationally consistent theory of ERM which can be related to management theories such as TQM represented an unexplored proposition. It was hypothesized that the presence of a TQM based system encourages the emergence and acceptance of an ERM based system. The empirical results of this dissertation support the TQM-to-ERM link. The results suggest that firms with advanced TQM systems in place also have more advanced ERM systems than firms just initiating TQM. In other words, ERM based systems will be stronger in firms as TQM based systems become more developed. What is being argued with these results is that TQM systems condition firms to be more interested in the need for an ERM system. When a TQM system precedes ERM, it increases the probability of an ERM system being present.

Because the two concepts of TQM and ERM share a similar focus, it makes sense to use many of the tools, methods, and practices of TQM in implementing an ERM based system. Given this perspective, the structure of ERM systems was expected to parallel or be very similar to that found in TQM systems. The results suggest that TQM can serve as a ready bridge to an ERM based system. TQM affects the resulting structure of the ERM system.

The results of this dissertation clarifies much of the confusion surrounding the relationship between TQM and ERM. It does so by pointing to the potential synergies between TQM and ERM. Meaning, firms which have developed capabilities in TQM will be more likely to develop the capabilities necessary for being environmentally responsible.

Furthermore, they will be able to develop the capabilities for being environmentally responsible more quickly than firms without a TQM based system because they will be able to reframe their learnings from existing quality tools, methods, and practices.

This dissertation has developed an integrated theory about how TQM based capabilities can be leveraged for ERM. It suggests that efforts should be coordinated to take advantage of the potential synergies between TQM and ERM. The means for capturing these synergies can be accomplished by using the MBNQA framework. Remember, the TQM measurement model was operationalized using a set of four multi-item scales corresponding to the four factors of the MBNQA framework. Likewise, ERM was operationalized in terms of the four first-order factors described by the MBNQA framework. The MBNQA framework was adapted to address environmental issues and furthermore, it was shown that the framework can be used as a basis for an integrative definition of ERM. The four-factor structures (e.g., Strategic Systems, Operational Systems, Information Systems, Results) of the initially hypothesized TQM and ERM CFA measurement models were retained in the final models. In other words, the TQM constructs were good predictors of the ERM constructs. This adaptation of the MBNQA framework suggests that quality principles can be seamlessly integrated into the practice of managing environmental issues.

APPENDIX

APPENDIX A

Measurement Instrument

The Automotive Industry Benchmarking Study

Michigan State University
The Eli Broad Graduate School of Management
East Lansing, Michigan

- This survey is part of a study which will help managers such as yourself better understand how the principles of Total Quality Management can be successfully applied to manufacturing concepts such as Environmentally Responsible Manufacturing. Furthermore, by agreeing to participate, you will receive a summary report which will allow you to benchmark your plant against the best practices of other plants in your industry.

- The differences between individual plants are of primary importance, and we are trying to understand the experiences of plant managers within your industry.

- Please try to answer **every** question to the best of your ability, even though you may not be 100% sure of your answer.

- ALL INDIVIDUAL RESPONSES WILL BE KEPT STRICTLY CONFIDENTIAL AND ONLY SUMMARY RESULTS WILL BE REPORTED. PLEASE ATTACH A BUSINESS CARD IN THE RETURN ENVELOPE IF YOU WOULD LIKE TO BE FORWARDED A COPY OF THE SUMMARY RESULTS UPON COMPLETION OF THE PROJECT.

If you have any questions or concerns, please feel free to contact:

Mr. Sime Curkovic
Michigan State University
N370 North Business Complex
East Lansing, MI 48824-1122
Tel. 517.353.6381
Fax. 517.432.1112
E-Mail: curkovi2@pilot.msu.edu

- Your job title: _____

- Number of years in your current position: _____ years

Please Read Carefully
For each program listed down the left side below, please indicate with a √ in the cell which best describes its status in your plant (only one √ per row please). If the program was successfully implemented, please indicate the year implementation was completed.

A = Not Applicable
B = Not Being Considered
C = Future Consideration
D = Assessing Suitability
E = Planning to Implement
F = Currently Implementing
G = Successfully Implemented (include year)

	A	B	C	D	E	F	G
QS 9000							
ISO 9000							
Plant-specific quality management system							
ISO 14000							
Participation in industrial voluntary environmental programs							
Participation in voluntary EPA programs (33/50, Green Lights, etc.)							
Plant-specific environmental management system							

Please Read Carefully
For the following questions about your plant's quality management system, you are asked to indicate your response by circling a number between the anchor points of the zero-to-ten scales.

Italicized measures represent measures which were retained in the final measurement model.

Factor 1 (F1): TQM Strategic Systems

V1:
Quality goals are clearly communicated to all plant personnel (1.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V2:
Quality is emphasized through a well-defined set of quality policies and procedures within your plant (1.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V3:
Customer quality requirements are used to establish a plant level quality strategy (2.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V4:
Adequate resources are provided to carry out quality improvements within your plant (3.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V5:
Plant and/or other company personnel actively interacts with customers to set reliability, responsiveness, and other standards for the plant (3.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V6:
Key factors for building and maintaining customer relationships are identified and used by your plant (3.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V7:
Formal and informal customer complaints are evaluated by your plant (3.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Factor 2 (F2): TQM Operational Systems

V8:
Human resources management within your plant is affected by quality plans (5.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V9:
An adequate amount of training in quality awareness is provided to hourly/direct labor employees within your plant (5.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V10:
An adequate amount of training in quality awareness is provided to managers and supervisors within your plant (5.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V11:
The work environment within your plant is conducive to employee well-being and growth (5.3)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V12:
The manufacturability of the products built within your plant is considered during the product design process (6.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V13:
Easy access for customers seeking information or assistance and/or comment and complain is provided (6.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V14:
Suppliers' facilities are visited regularly by plant and/or other company personnel (6.3)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Factor 3 (F3): TQM Information Systems

V15:
Quality data within the plant is made visible - displayed at work stations (4.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V16:
Quality data within the plant is provided in a timely manner (4.1)

Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V17:
Quality data is made available to all employees within your plant (4.1)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V18:
Benchmark data is used to improve quality practices within your plant (4.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V19:
Procedures have been developed for monitoring key indicators of plant performance (4.2)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V20:
Procedures have been developed for monitoring key indicators of customer satisfaction (4.3)
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Please indicate whether or not your plant regularly monitors the following quality measures by circling "yes" or "no". If so, please estimate the magnitude of changed experienced in each area over the last three years. For example, if after-sales customer complaints have decreased by over 100% over the last three years, then circle "-100% or >". Please try to answer every question to the best of your ability.

Factor 4 (F4): TQM Results

Is this measure used?
Estimated % Change
(please circle one)

V21:
After-sales customer complaints (7.1) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V22:
Customer rejection of our products (e.g., manufacturing defects) (7.1) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V23:
Defect rates/cost (7.2) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V24:
Employee absenteeism (7.3) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V25:
Cost of quality (e.g., inspection and testing) (7.2) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V26:
Employee grievances (7.3) *YES NO*
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V27:
Employee turnover (7.3) YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V28:
On-time delivery of purchased parts (7.4) YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V29:
Total cost of purchased parts (7.4) YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

Please Read Carefully
For the following questions about your plant's environmental management system, you are asked to indicate your response by circling a number between the anchor points of the zero-to-ten scales.

Factor 5 (F5): ERM Strategic Systems

V30:
Environmental goals are clearly communicated to all plant personnel
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V31:
Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V32:
Employees throughout your plant are evaluated on environmental performance results
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V33:
Environmental requirements are used to establish a plant level environmental strategy
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V34:
Adequate resources are provided to carry out environmental improvements within your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V35:
Processes have been developed to respond to customer/stakeholder (e.g., local community) questions and concerns regarding the environmental practices of your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V36:
Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Factor 6 (F6): ERM Operational Systems

V37:
Human resources management within your plant is affected by environmental plans
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V38:
An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V39:
An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V40:
Environmental issues are included in the product design process
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V41:
Environmental issues are included in the process design process
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V42:
Performance on environmental dimensions is considered during supplier evaluations by plant and/or other company personnel
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Factor 7 (F7): ERM Information Systems

V43:
Environmentally-related information (e.g., changes in regulations) is used on an on-going basis by your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V44:
Information about best-in-class environmental performance is tracked and recorded by your plant
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V45:
Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V46:
Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

V47:
Cost accounting has been used extensively in your plant for capturing and reporting environmental problems and costs
Strongly Disagree <-- 0 1 2 3 4 5 6 7 8 9 10 --> Strongly Agree

Please indicate whether or not your plant regularly monitors the following <u>environmental</u> measures by circling "yes" or "no". If so, please estimate the magnitude of changed experienced in each area over the last three years. For example, if the volume of hazardous waste has decreased by over 100% over the last three years, then circle "-100% or >". Please try to answer every question to the best of your ability.

Factor 8 (8): ERM Results

Is this measure used?
Estimated % Change
(please circle one)

V48:
Pre/post consumer recyclability content of direct materials YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V49:
Volume of wastewater discharges YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V50:
Tons of solid waste landfilled YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V51:
Volume of hazardous waste YES NO
+100% or > +80% +60% +40% +20% 0% -20% -40% -60% -80% -100% or >

V52:
Tons of hazardous air emissions *YES* *NO*
(CFCs, VOCs, carbon dioxide,
methane, sulfur oxides, etc.)
+100% or > *+80%* *+60%* *+40%* *+20%* *0%* *-20%* *-40%* *-60%*
-80% *-100% or >*

Plant Characteristics
(Source: Klassen 1995)

- Is your parent firm (√ all that apply)?

  _____ publicly traded
  _____ a foreign-owned subsidiary/transplant
  _____ privately owned
  _____ a joint venture

- What was the approximate sales volume from all production units shipped from your plant (*will be kept strictly confidential*):

  during 1995? $_____ during 1996? $_____

- Is your hourly/direct labor workforce represented by a union?
  YES or NO

- Rate your plant's ability to effectively manage labor-management relations (circle a number):
  Poor <-- 0 1 2 3 4 5 6 7 8 9 10 --> Excellent

- Does your plant have any dedicated "environmental" people or a department?
  YES or NO
  ...if yes, how many people (or person equivalents)?
  _____ people

- What is the typical rate of return (hurdle rate) or payback period that is required for capital projects which require approval (fill in blank and circle correct unit)
  _____ % or YEARS

- Is a different rate of return or payback period required for capital projects that reduce any negative impact of operations on the natural environment?
  YES or NO
  ...if yes, what is the rate of return or payback period?
  _____ % or YEARS

- What is the approximate average age of your plant's production equipment?
  _____ years

- Has your plant experienced a major environmental crisis within the last five years (e.g., oil spills, gas leaks)?
  YES or NO

- Please indicate your estimate of the probability that this plant will be operating at or above its current production level (circle the probability for each time horizon):

	no chance				**moderate probability**						**with certainty**
next year	0	10	20	30	40	50	60	70	80	90	100
in five years	0	10	20	30	40	50	60	70	80	90	100

Attach your business card if you wish to receive a copy of the final report based on the summarized responses to this survey. Thank you very much for your valuable time.

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