Investigating the Linkage Between Total Quality Management and Environmentally Responsible Manufacturing

Sime Curkovic, Steven A. Melnyk, Robert B. Handfield, and Roger Calantone

***Abstract*—This paper explicitly examines the relationship that exists between total quality management (TQM) and environmentally responsible manufacturing (ERM) systems. It has been presumed in numerous past studies that such a relationship does exist. It has been argued that those firms that have successfully implemented a TQM system are better positioned to successfully implement an ERM system. This relationship, however, has not yet been statistically and empirically evaluated. In this study, the authors evaluate this relationship using a large-scale survey of plant managers as the data source and confirmatory factor analysis and structural equation modeling as the statistical tools. The study develops a series of measures for various aspects of both TQM and ERM. The results show that there is indeed a strong relationship between TQM and ERM. In many ways, ERM is conditioned by the presence of TQM. Furthermore, ERM systems have a parallel structure when compared to TQM systems.**

***Index Terms*—Confirmatory factor analysis, environmentally responsible manufacturing, structural equation modeling, total quality management.**

I. Introduction

ENVIRONMENTALLY responsible manufacturing (ERM) is a relatively new concept that 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 [72]. Fundamental to ERM is the recognition that pollution, irrespective of its type and form, is ultimately waste. Based on past experiences with the concepts of just-in-time (JIT), total quality management (TQM), and time-based competition (TBC), we know that waste is any activity or product which consumes resources or creates costs without generating any form of offsetting stream of value [120]. By minimizing waste, the 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 [130], [136], [138]. When viewed in this light, it would be expected that more managers be interested in the development and use of ERM-based systems. However, for most firms, ERM has yet to achieve the same degree of acceptance as have JIT, TQM, and TBC [10], [50], [60], [61], [102], [103].

It has been suggested that organizations with TQM systems in place are more inclined to undertake ERM-based systems than companies with less commitment to TQM [91], [93], [94]. This implies that a companys ability to reframe learnings from TQM is crucial to the successful implementation and use of ERM-based systems and procedures. Limited evidence has been presented that TQM systems are being used as models for ERM systems. The normative literature and case studies that dominates the ERM field suggests, but does not explicitly recognize, that in TQM, there is an explainable, understandable, and documental path to ERM.

Unfortunately, while case studies and deductive arguments have emphasized TQM's role in ERM, researchers have not supported these arguments with extensive systematic empirical analyzes. The overarching goal of this study is to investigate the theoretical linkage between TQM and ERM by answering the following two 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? These questions collectively reflect an interesting premise—that ERM systems can be 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 [48], [50], [65], [80], [99], [100], [106], [113], [129]. 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 focuses more on pollution in the form of air emissions and solid and hazardous waste. Because the two concepts share a similar focus, it makes sense to use many of the TQM tools, methods, and practices in implementing an ERM-based system. Given this perspective, the structure of ERM systems can be expected to be very similar to that found in TQM systems. A linkage between overall TQM and ERM systems is also expected. Given this premise, this study is interested in assessing whether such a relationship between TQM and ERM systems exists. This study is also interested in exploring any significant similarities and differences between the structures of these two systems.

This paper begins by reviewing the ERM literature. This review serves to establish the relationship between TQM and ERM as a major research stream. Operational frameworks for TQM and ERM are then developed. This section concludes with a comparative assessment of several TQM frameworks to de-

Manuscript received December 23, 1998. Review of this manuscript was arranged by Department Editor Burton V. Dean.

S. Curkovic is with the Management Department, Haworth College of Business, Western Michigan University, Kalamazoo, MI 49008 USA (e-mail: sime.curkovic@wmich.edu).

S. A. Melnyk, R. B. Handfield, and R. Calantone are with the Department of Marketing and Supply Chain Management, the Eli Broad Graduate School of Management, Michigan State University, East Lansing, MI 48824 USA.

Publisher Item Identifier S 0018-9391(00)09608-2.

termine which framework best fits the conceptual requirements of a TQM system. From this assessment, the Malcolm Baldrige National Quality Award (MBNQA) framework emerges as the most consistent with the definition of TQM (it is subsequently used as the basis for the operational frameworks of TQM and ERM). From this theoretical foundation, we proceed to the data analysis section. Here, a two-stage process is used. In the first stage, the TQM and ERM measurement models are first developed and validated using confirmatory factor analysis (CFA). In the second stage, the measurement models are "fixed" when the overall full structural equation model (SEM) is estimated. The SEM is used to assess the TQM-to-ERM linkage. The final section concludes with a discussion of the implications of this paper's findings for managerial decision-making.

II. ERM—The Literature Review

The body of literature dealing with ERM is vast, diverse, and ever-growing. However, from this literature, three streams of research can be identified pertaining to ERM. The first stream focuses on investigating the relationship between ERM and business performance. This relationship has been the subject of great debate in the literature. To date, empirical research results pertaining to the potential positive relationship between ERM and corporate performance have been mixed, with ambiguous or conflicting conclusions [9], [27], [91], [92], [145]. The second stream of research pertaining to ERM focuses on identifying what constitutes an effective and efficient ERM system. A majority of the writings within this stream have provided managers with primarily normative prescriptions and managerial guidelines, but it has yet to address how to develop and successfully implement ERM [91], [149].

The final stream of research, and the focus of this study, looks at whether there are any precedents to the emergence of ERM. For the most part, this stream has focused on the relationship between TQM and ERM. Although originally applied 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 [3], [50], [59], [64], [69], [73], [75], [90], [99], [100], [102], [106], [109], [116], [123], [126], [129], [136], [143], [150], [152], [157], [159].

Some researchers, such as Makower [102] and Willig [157], bring together first-hand reports on how leading companies are going beyond meeting regulatory compliance to gain 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.

What is being argued within this stream 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 effects. First, it increases the probability of an ERM system being present. The systematic view of TQM, encompassing 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.

For example, based on eight detailed case studies of Dutch companies, Cramer and Roes [37] 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.

3M, AT&T, and Proctor & Gamble are also examples of companies which were among the first to extend their TQM initiatives to ERM [127], [134], [143]. These companies utilized TQM approaches to work toward a goal of zero waste discharges. TQM tools that were integrated into their waste minimization programs included Pareto analysis and control charts to signal pollution problems in the manufacturing process. Benchmarking techniques were also used to assess conformance with elements of their own environmental management systems. Each company now reports aggregate savings and significant environmental benefits generated by using TQM concepts in environmental management.

Sonoco's experience with materials reclamation illustrates how it used quality management principles to integrate environmental objectives [126]. 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. 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.

It has been suggested and presumed by several researchers, through conceptual analyzes and case studies, that significant benefits arise from applying what has been learned about TQM to environmental issues. This study statistically and empirically investigates whether the presence of a relationship between TQM and ERM systems exists, and, if so, it explores the nature of this relationship. It is hoped that this research will help resolve much of the confusion surrounding the assumed relationship between TQM and ERM systems.

III. Developing Operational Frameworks of TQM and ERM

The observed parallels between TQM- and ERM-based systems have been noted by numerous researchers. They all point out that 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;
7) demand continual self-assessment and improvement.

TABLE I
THE BEST DEFINITIONS OF TQM

Associated Traits of TQM	A	B	C	D	E	F	G	H	I	J	MBNQA
Continuous Improvement	X	X	X	X	X			X	X	X	X
Meeting Customer's Requirements	X	X			X	X	X				X
Long-Range Planning	X			X				X	X	X	X
Increased Employee Involvement	X	X	X	X		X		X		X	X
Process Management		X		X	X	X	X	X	X	X	X
Competitive Benchmarking				X		X		X	X	X	X
Team-Based Problem-Solving	X		X	X		X		X	X		X
Constant Measurement of Results	X		X	X	X	X	X			X	X
Closer Relationships with Customers	X	X			X	X		X	X	X	X
Management Commitment	X	X	X	X	X	X	X	X	X	X	X
10 Traits Total:	8	6	5	8	6	8	4	8	7	8	10

(A) Juran; (B) Deming; (C) Crosby; (D) Saraph et al. (1989); (E) Flynn et al. (1994); (F) Powell (1995); (G) ISO 9000; (H) Anderson et al. (1994); (I) Black and Porter (1996); and Ahire et al. (1996)

What is implied by these similarities is that an operational framework of TQM can be adapted for ERM. Therefore, developing an operational framework of ERM begins with identifying an operational framework that best fits the definition of TQM.

During the review of the TQM literature, 11 TQM frameworks were identified. These frameworks were examined to uncover the similarities and differences encountered when operationalizing the TQM construct. To better structure this comparison, several definitions of TQM (drawn from sources such as Evan [51], Logothetis [96], and Melnyk and Denzler [110]) were identified. From these sources, ten traits associated with TQM were developed. Using these traits, the eight frameworks and the constructs contained within them were reviewed to determine which framework was most consistent with the definition of TQM.

Although different TQM proponents emphasize different traits, an exhaustive review of three research streams (e.g., ancedotal, empirically-based, and formal assessment processes) reveals that TQM encompasses the ten traits shown in Table I. We chose to focus on these ten for three key reasons:

1) the literature identifies them as intrinsic parts of TQM;
2) taken as a set, they thoroughly cover the people, process, and integration aspects of TQM; and
3) industry experts confirmed their relevance.

As can be seen in Table I, the MBNQA framework best satisfies the requirements of TQM. The MBNQA framework was the most comprehensive since it covered all ten traits associated with TQM.

The MBNQA criteria for performance excellence represent a comprehensive, integrated framework for the management of modern enterprises. The criteria have evolved based upon the accumulated knowledge of best management practices and the collective wisdom of practitioners and experts [52]. However, the criteria have also been grounded in formal theory by design and validated via empirical research and analysis.

Several researchers have adopted the MBNQA framework as the basic operational model of TQM. For example, Dean and Bowen [41] used it to explore the relationship between the principles of TQM and management theories. Black and Porter [20] used it to develop their TQM survey questions, while Capon, Kaye, and Wood [28] used it to identify measures of TQM success (also see, [30], [43], and [60]). In cross-fertilization attempts, which are essentially the basis for using the TQM literature in this study, one is compelled to search for a framework that has been validated through generally accepted theoretical and empirical research methodologies. Such research, while preliminary, does generally exist with respect to the MBNQA criteria.

It also becomes important to recognize that the MBNQA criteria have evolved over the years and it has now become a model for major strategic initiatives that go beyond TQM. In fact, since 1997, the word "quality" does not appear in any of the headings for the categories. It is now broad enough to be used as a framework for quality and/or environmental issues. This framework can be adapted right away to develop ERM measures and constructs that are systematic in nature. For example, Eastman Kodak, a former recipient of the MBNQA, has started to apply the principle of TQM to its environmental management program using the MBNQA criteria. Also, some researchers (e.g., [107], [151]) describe how the implementation of ERM can be made more successful by integrating it into a TQM system embedded in the criteria associated with the MBNQA framework.

In 1994, the Council of Great Lakes Industries (CGLI) also developed a primer and self-assessment matrix for companies to develop and improve their ERM programs. The CGLI program is based on categories adapted from those used in the MBNQA framework. According to CGLI, although the MBNQA annually recognizes U.S. firms 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.

A. Drawing Parallels Between TQM and ERM

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. Since the MBNQA framework is the most consistent with the definition of TQM and is often used as the operational framework of TQM, the categories associated with the framework will be used to draw parallels between TQM and ERM. Parallels are drawn to further reinforce from the previous section that the two concepts are so closely linked that an operational framework of TQM can be adapted for ERM. The results of this comparison are shown in Table II.

IV. Operationalization of ERM

The ERM construct will be conceptualized in terms of the four basic factors described by the MBNQA framework. The MBNQA framework is described as three related subsystems [51], [52]:

1) "*strategic*" categories of *leadership*, *strategic planning*, and *customer/market focus*;
2) "*operational*" categories of *human resource development* and *process management* (which lead to "*results*");
3) "*information*" category that serves as the foundation for the other two subsystems.

In summary, ERM is hypothesized to consist of the following factors:

1) ERM strategic systems;
2) ERM operational systems;
3) ERM information systems;
4) ERM results.

These factors and their proposed measures span the entire range of activities deemed critical by the MBNQA framework (see Appendix A for definitions of these factors and the selection of items).

V. Research Design

In past studies dealing with TQM and ERM, field/case studies have been the predominant research methodology [2], [8], [97], [104], [111], [121], [132], [135]. However, this methodology was not appropriate to this study and its objectives. Given our interest in evaluating the linkages between TQM and ERM systems, a more quantitative approach was needed. As a result, it was decided to use a large mail survey to provide data and to analyze the resulting data with a combination of confirmatory factor analysis (CFA) and structural equation modeling (SEM).

At the heart of this methodology was a two-phase approach. During the first phase, preliminary scale development was conducted using interviews from managers. In the second phase, a large-scale survey was designed and implemented that was intended to validate the various scales for measuring the underlying constructs associated with TQM and ERM, and the nature of their relationship. This combination allowed for the exploitation of the strengths of both case studies and surveys while reducing the problems associated with both.

Using a protocol similar to much of the research in operations strategy, a single industry was chosen [1], [140], [148], [154]. This restriction permitted the control of several variables that often differ between industries, including the scope and complexity of quality and environmental concerns. However, for the industry selected, the types of environmental issues and range of ERM programs used had to offer sufficient variability for study (a requirement of any type of external generalizability). To empirically test a model dealing with TQM and ERM, an ideal industry should possess three primary characteristics [1], [2], [90], [91]:

1) high degree of variation in ERM programs;
2) leader in the implementation of progressive quality management strategies;
3) competitive marketplace.

Based on these criteria, the automotive industry was chosen. More specifically, the sample was targeted across a four-digit SIC code within the U.S. automotive industry—motor vehicle parts and accessories (SIC 3714). These are 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.). An exhaustive and comprehensive database of 2945 manufacturing facilities from this SIC code was obtained.

TABLE II
DRAWING PARALLELS BETWEEN TQM AND ERM

Leadership

- Senior management acts as a driver for TQM implementation [71][84][85][86][88][154].
- The critical guide and motivator for the development and implementation of ERM must also come from senior management [8][14][50][78][102][142][161].

Strategic Planning

- TQM requires that product quality be defined from the customer's viewpoint and exceeding the customer's expectations can only be accomplished when organizations strategically plan and organize their resources [40][63][84][163].
- ERM requires 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 [76][78][50][91][161].

Customer and Market Focus

- TQM is based on an organization's knowledge of its customers, overall customer service system, responsiveness, and ability to meet customer requirements and expectations [13][54][79][87][94].
- ERM also requires the adoption of response systems to handle the most basic of customer/stakeholder concerns or requirements [36][64][81].

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 [11][62][135][165].
- ERM also requires extensive information collection and analysis and the latest technology for managing information resources [24][36][56][81][118].

Human Resource Management

- TQM demands that all aspects of human resource management (e.g., manpower planning, recruitment and staffing, training and development, performance appraisal, and reward systems) assume strategic roles [32][46][74][85][86][95][98][117].
- The best results from ERM also can be only obtained when there is a high level of involvement and commitment from trained people [35][37][49][68][104][106][161].

Process Management

- The management of process quality examines how key process 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 [18][19][62][63][87][114][151].
- 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 [21][91][106][157][161].

Business Results

- TQM requires that companies monitor and improve their quality performance based on objective measures of quality and operational results [33][55][58][134].
- Whenever ERM is implemented, measures should be identified to determine if the systems is delivering the desired results [36][64][104].

Another factor that made this sector highly appropriate for this study involved the current environmental issues facing this industry. These included the implementation of amendments to the Clean Air Act, along with other waste concerns. Individual plants within the industry were pursuing a variety of environmental strategies, apparently with mixed results. Most plants were cognizant of the environmental issues, and a minority were reportedly leading the industry in attempts to improve performance in advance of the standards. However, many other firms have adopted a "wait and see" approach, indicating a potentially high degree of variability.

The automotive industry was also appropriate because it was a leader in implementing progressive quality management strategies in the U.S. [33]. The industry has already been the focus of many empirical studies which address quality management [1], [39], [158]. 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 [45].

The unit of analysis for empirical validation was the individual plant, rather than a strategic business unit (SBU) or another subsidiary level. The plant was the level of implementation for most quality management programs, and has been used in numerous other empirical studies related to quality [1], [47], [131]. Many options about investment, other than those pertaining to quality management (e.g., environmental technologies), were also identified at the plant level, either by operating personnel, external consultants, or corporate specialists.

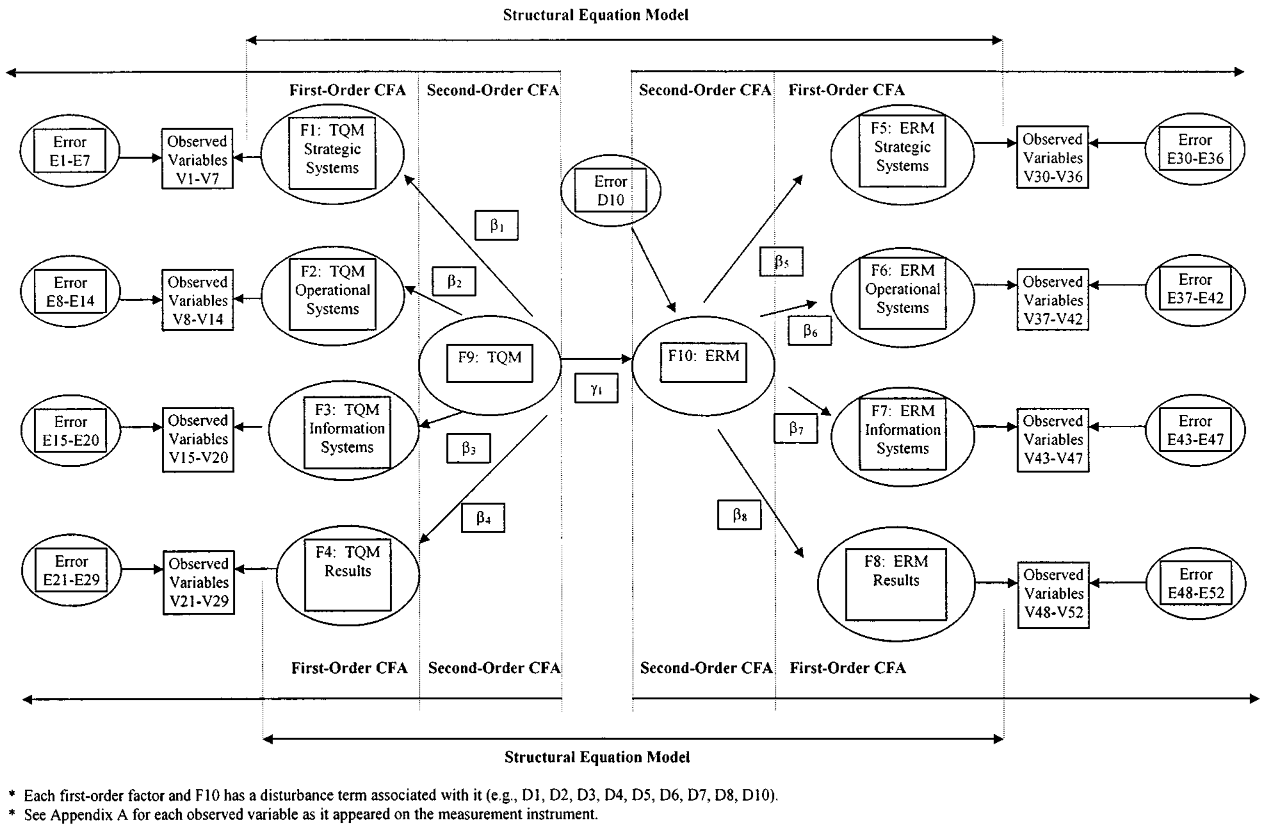


Fig. 1. Research model.

As mentioned by Klassen [90], [91], an environmental investment portfolio is most often 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.

Ideally, information should be gathered from multiple respondents at each site to minimize the potential for bias from a single respondent [112], [119]. 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 study. Such a strategy was not adopted because the response rate would likely be depressed to a critical level. Therefore, only single respondents (plant managers) were targeted for the study.

The pretest revealed that plant managers would be qualified to answer the questions objectively, while responses from quality and environmental managers would be suffer from the problem of social desirability. Environmental specialists might believe there is an "ideal" response, or be overly positive or negative, and hence, give socially desirable answers that do not reflect actual practices. However, it is acknowledged that the use of multiple informants would enrich the data further and eliminate some of the biases and inaccuracies.

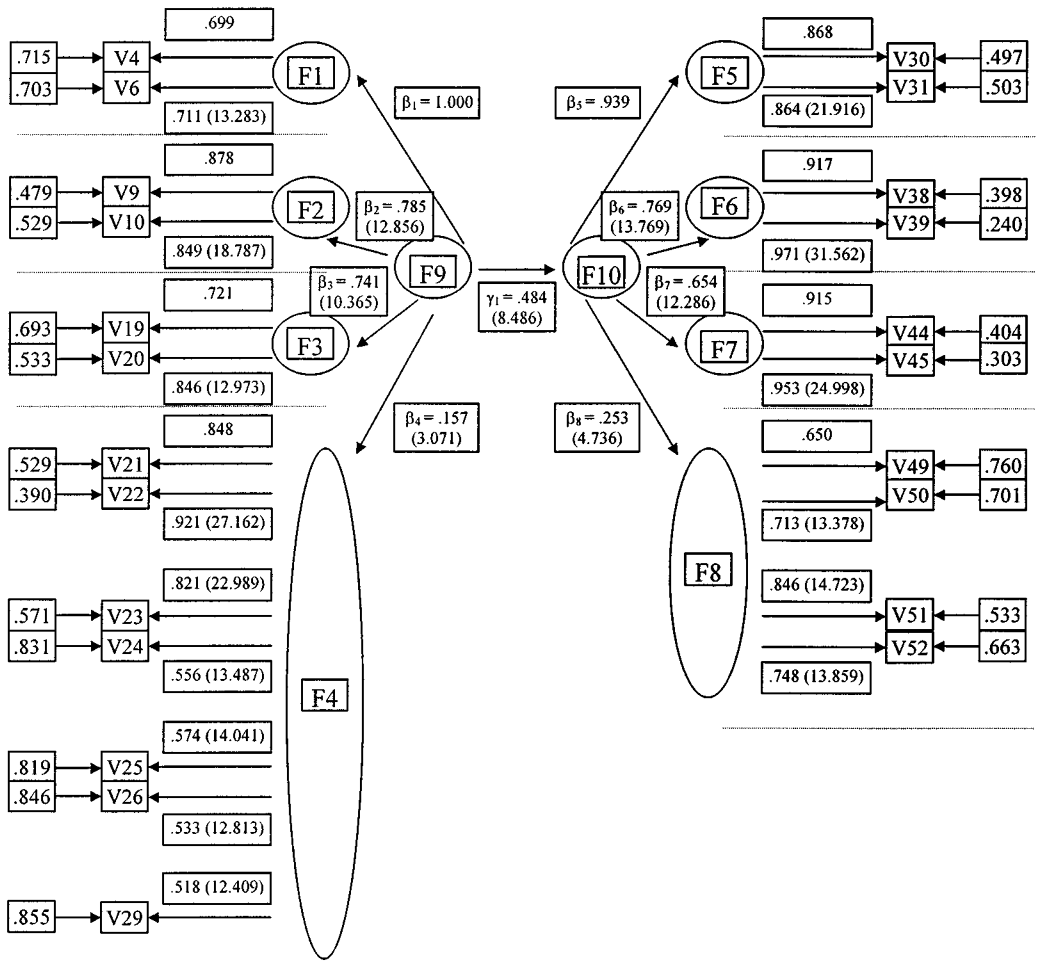
VI. Data Analysis

The data analysis uses a two-stage process in which the TQM and ERM measurement models are first developed and validated, using confirmatory factor analysis (CFA). The measurement models are then "fixed" in the second stage, when the overall full structural equation model (SEM) is estimated. 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 that examines the TQM-to-ERM linkage. Researchers are now proposing this two-stage approach because an accurate representation of the reliability of the observed (manifest) variables is best accomplished in two stages to avoid interaction of the measurement models and the overall SEM model [4], [70], [89], [156].

The hypothesized overall model is portrayed in Fig. 1. 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. Fig. 1 shows both the second-order TQM CFA measurement model and the 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.

Expressed more formally, the CFA models, as shown in Fig. 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;



* 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

FACTOR (Fs) & VARIABLE (Vs) LABELS

F1 = Factor 1 = TQM 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 = TQM 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

Fig. 2. The final full structural equation model (SEM).

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

The next section provides a summary of the data analysis findings. The analyzes are provided in Appendix B.

A. Summary of Data Analysis Findings

In summary, all of the causal paths specified in the hypothesized model (Fig. 1) were found to be positive and statistically significant (see Fig. 2). 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);
3) TQM (F9) on ERM (F10).

In other words, all of the structural paths from TQM to TQM strategic systems ($\beta_1 = 1.000$), TQM operational systems ($\beta_2 = 0.785, t = 12.856$), TQM information systems ($\beta_3 = 0.741, t = 10.365$), and TQM results ($\beta_4 = 0.157$, $t = 3.071$) were positive and significant as hypothesized, and, ERM-to-ERM strategic systems ($\beta_5 = 0.939$), ERM operational systems ($\beta_6 = 0.769, t = 13.769$), ERM information systems ($\beta_7 = 0.654, t = 12.286$), and ERM

F3 = Factor 3 = TQM 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 = TQM 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

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.)

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

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

Fig. 2 (cont'd). The final full structural equation model (SEM).

results ($\beta_8 = 0.253, t = 4.736$) were positive and significant as hypothesized. The structural path from TQM to ERM ($\gamma_1 = 0.484, t = 8.486$) 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, all of the hypothesized paths were significant and were subsequently left in the model.

VII. Discussion of Results

A. Assessing the Fit Between the TQM/ERM Measures and Constructs

In the first set of relationships, we were interested in examining the fit between the measures and the constructs that these were intended to capture. This analysis can be answered at two levels. At the first, we focus on determining the extent to which there is a unique and theory-driven relationship between measures and constructs. As noted previously, the TQM and ERM constructs were each conceptualized in terms of the four basic factors described by the MBNQA framework:

1) strategic systems;
2) operational systems;
3) information systems;
4) results.

The results show that the measures do indeed load on the appropriate constructs. More important, these measures load on no other construct. As a result, we can say that the metrics generated by the MBNQA do indeed measure the underlying unobserved behavior that they are supposed to measure.

What is more interesting is the second set of findings involving the number of measurement or manifest variables that were ultimately identified as best loading on each construct. Initially, for each of the four constructs, we introduced four or more measures. During the analysis, we noted that several of the measures were dropped from further consideration.

B. TQM Strategic Systems

For this system (F1), only two of the original seven measures were retained in the final TQM CFA measurement model. These two measures were 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). These two measures include issues as they pertain to strategic planning (V4) and customer/market focus (V6). The other four measures were eliminated as not providing as strong a relationship as these two remaining measures. This study provides empirical support that a TQM-based system must encompass an organization's knowledge of its customers, responsiveness, and ability to meet customer requirements and expectations.

C. TQM Operational Systems

For the TQM operational systems construct (F2), we found that only two of the original seven measures associated with this construct were retained in the final TQM CFA measurement model. These two were 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 these measures deal with human resource development. The other measures associated with process management were dropped. This last finding is interesting in that it was not excepted. Given the heavy emphasis in the TQM literature on process awareness and the need for better or more effective process management, we had expected some degree of process management to be present in the retained set of measures. One possible reason for this observed result can be found in the need for training, as it pertains to human resources. Many authors have used case studies and anecdotal examples to contend that TQM can be best achieved when there is a high level of commitment and involvement from people [32], [74], [85], [86], [98], [117]. Several other articles identify training and development at all levels as the single best strategy to improve quality [46], [95]. This study provides empirical support that TQM demands that human resource management, in the form of training and development, assume strategic roles.

D. TQM Information Systems

This construct (F3) retained two of the original six measures in the final TQM CFA measurement model. These were 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). These two measures refer to the quality of the metrics, both internally (within the plant) and externally (at the customer). These measures point the need for managers to develop and have a balanced view of performance and to have the information necessary to maintain this view. Furthermore, the importance of timely, reliable, and adequate information in the development and implementation of TQM has been noted by several researchers [11], [62]. The importance of the expanded role of information technology and systems in integrating information from inside and outside the company (e.g., customers) has also been identified in the literature [125], [155]. This study supports that information and analysis can help reinforce the implementation of TQM practices.

E. TQM Results

Of the four constructs assessed within this study, this construct retained the largest number of measures in the final TQM CFA model. Of the nine original measures, seven were kept:

1) after-sales customer complaints (V21);
2) customer rejection of our 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);
7) total cost of purchased parts (V29).

This more complex relationship between the metrics and the underlying latent variable can be explained as follows. TQM requires that companies monitor and improve their quality performance based on objective measures of quality results. Researchers have suggested that superior quality performance is the result of understanding the factors that determine quality performance [58], [124]. Other studies have similarly concluded that firms need to focus on improving quality of every work process as measured by the needs of internal and external customers [33], [55]. This study provides empirical support that monitoring performance is integral to TQM. What this means is that measures should be identified and used to determine if the system is delivering the desired results.

F. ERM Strategic Systems

ERM strategic systems (F1) retained two measures in the final ERM CFA measurement model: 1) environmental goals are clearly communicated to all plant personnel (V1) and 2) environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant (V2). 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. Research suggests, but does explicitly recognize, that the critical guide and motivator for ERM must come from senior management leadership [8], [36], [50], [78], [102], [103], [107], [132], [151]. This study provides empirical support that senior executives must reinforce ERM values in their organizations.

G. ERM Operational Systems

ERM operational systems (F2) 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 (V9) and 2) an adequate amount of training in environmental 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, while the other measures associated with process management were dropped. 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 [34], [35], [37], [65], [68], [104], [106], [142], [151]. This study provides empirical support that ERM demands that human resource development, in the form of training and development, assume strategic roles.

H. ERM Information Systems

ERM information systems (F3) 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 (V15) and 2) environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis (V16). Bracken [24] 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 [81], [118]. The importance of information and benchmarking 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.

I. ERM Results

ERM results (F4) retained four measures:

1) volume of waste water discharges (V20);
2) tons of solid waste landfilled (V21);
3) tons of hazardous waste (V22);
4) tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur dioxides, etc.) (V23).

According to Johannson [81], ERM requires that organizations monitor and improve their environmental performance based on objective measures. ERM results can be particularly effective in demonstrating the value of environmental efforts to management. 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.

J. Simplifying the Underlying TQM and ERM Measurement Models

The results presented in the preceding section are interesting when taken construct by construct. However, when taken as a whole, another interesting finding emerges from the empirical data. Originally, the MBNQA framework had been operationalized as consisting of four constructs or latent variables. These four constructs were measured using 30 measurements or manifest variables (TQM strategic systems—7; TQM operational systems—7; TQM information systems—6; and TQM results—9). Of these 30 measures, only 13 were ultimately retained in the TQM CFA measurement model (TQM strategic systems—2; TQM operational systems—2; TQM information systems—2; TQM results—7). The ERM construct was also conceptualized in terms of the four basic factors described by the MBNQA framework using 23 measurements (ERM strategic systems—7; ERM operational systems—6; ERM information systems—5; and ERM results—5). Of these 23 measures, only ten were retained in the ERM CFA measurement model (ERM strategic systems—2; ERM operational systems—2; ERM information systems—2; and ERM results—4).

These are interesting results because the ultimate TQM and ERM models can be viewed as simpler, less-complex models. Simplification is an important goal of any research study. Simpler models are easier to study and explain. They are also more powerful. As noted within the well-known theorem of "Occam's Razor," parsimony is a desired trait of every model. What these empirical results point to is a more parsimonious model of the relationship between the measures and the various constructs.

Often, in the search for substantive relationships, an emerging field tends to overlook methodological issues such as measurement [133]. This study has made an attempt to preclude such a situation in the areas of TQM and ERM. The high dropout rate for items within the four factors resulted from the fact that we were in the early stages of research and that an important part of what we were contributing was the development of scales. Thus, we expected that not all measured variables would go into the factors as initially hypothesized. It is acknowledged that under the current measurement scheme some important traits may have been omitted or some overlapping measures selected. However, the evidence presented in this study regarding the existence and structure of TQM and ERM is necessary for future studies to refine our conceptualization as well as to remove deficiencies in the measures.

The model in Fig. 2 should therefore not be regarded as a complete or true model for measuring TQM and ERM. Doing so would cause us to ignore numerous important components such as process management, resource allocation, stakeholder views, and many other issues. The model in Fig. 2 would actually instruct us to only consider issues such as internal communication, training, and benchmarking. This would prescribe too-narrow views of TQM and ERM. It therefore becomes necessary for future research to build upon our work. Future research will hopefully identify cases where the dropout rate of items within the factors is significantly lower than in our study.

K. Assessing the Fit Between the MBNQA Framework and TQM/ERM

More important and of greater interest, the findings presented in this study draw a unique picture of the TQM and ERM *process*. To attain TQM and ERM status, a firm must first attain certain performance requirements, as captured by the various measures. As these performance traits are attained, the firm is able to achieve the implementation of certain critical TQM and ERM subsystems (i.e., strategic systems, operational systems, information systems, and results). Each subsystem is required to be in place before the firm can hope to claim that it has a complete TQM and ERM system present. In short, we can argue that the MBNQA is more than simply a framework: it is a process model. What makes this finding so strong is that it is not based on simply anecdotal or case data, nor is it based on the experiences of "leading-edge" practitioners. Rather, what we have here are findings based on a cross section of experiences of firms within a specific industrial sector.

L. Assessing the Relationship Between TQM and ERM

The overarching goal of this study 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 study support the TQM-to-ERM linkage. 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.

Companies can utilize TQM approaches to develop 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) 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;
3) team orientation that uses the knowledge of employees to develop solutions for waste problems.

ERM systems can be viewed as 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 [50], [106], [113], [129]. 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.

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 that paralleled one another in the TQM- and ERM-based systems were very similar in magnitude and nonvariant. These results suggest that TQM can serve as a ready bridge for an ERM-based system.

VIII. Concluding Comments

This study 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 that 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 study 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.

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 could be used as a basis for an integrative definition of ERM. The four-factor structures (e.g., strategic systems, operational systems, information systems, and 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.

Appendix A
Operational Measures of TQM and ERM

A. TQM Measures

This section deals with generating items that represent manifestations of the four factors/latent variables associated with TQM. Multi-item scales for each factor serve as parsimonious representations of unidimensional factors, corresponding in similarity to each of the four factors associated with the MBNQA framework (e.g., TQM strategic systems, TQM operational systems, TQM information systems, TQM results). Definitions of these factors and the selection of items were developed directly from the MBNQA criteria. Each manifestation is measured with an item in a scale. The corresponding MBNQA criterion is shown in parentheses following each measure. Factor items were constructed through confirmatory factor analysis (using loadings of 0.50 as a minimum value for inclusion of an item in a factor) and reliability analyzes (Cronbach's coefficient alpha). Items which did not have significant factor loadings or which did not demonstrate sufficient discriminant validity, were by definition not representative of the factor, and were subsequently removed from the model (as indicated by an asterisk in the descriptions that follow).

The focus of the measures is on real decisions made by plant managers 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 questions were measured using an 11-point bipolar scale (e.g., $0 =$ strongly disagree, $10 =$ strongly agree). The following sections list the factors and the scales used in the study.

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 [104].

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). *

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 [104].

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). *

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 [104].

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).

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 [104]. 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).

B. *ERM Measures*

This section deals with generating items that represent manifestations of the four factors/latent variables associated with ERM. Multi-item scales for each factor will serve as parsimonious representations of unidimensional constructs, corresponding in similarity to each of the four factors associated with the MBNQA framework. Definitions for these factors and the selection of items were developed from the MBNQA criteria, the ERM 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.

Factor 5 (F5): ERM strategic systems: 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 [36], [64], [104], [107].

V30: Environmental goals are clearly communicated to all plant personnel [64].

V31: Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant [36], [107].

V32: Employees throughout your plant are evaluated on environmental performance results [36], [107]. *

V33: Environmental requirements are used to establish a plant level environmental strategy [36], [107]. *

V34: Adequate resources are provided to carry out environmental improvements within your plant [36], [107]. *

V35: Processes have been developed to respond to customer/stakeholder (e.g., local community) questions and concernsregarding the environmental practices of your plant [66]. *

V36: Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant [36], [107]. *

Factor 6 (F6)—ERM operational systems: 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 [36], [104], [107].

V37: Human resources management within your plant is affected by environmental plans (McGee and Bhushan [36], [107]). *

V38: An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant [36], [107].

V39: An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant [36], [107].

V40: Environmental issues are included in the product design process [26]. *

V41: Environmental issues are included in the process design process [26]. *

V42: Performance on environmental dimensions is considered during supplier evaluations by plant and/or other company personnel [26]. *

Factor 7 (F7)—ERM information systems: An ERM information system is defined as the effectiveness of an organization's collection, analysis, and use of information for environmental planning and improvement [36], [107].

V43: Environmentally-related information (e.g., changes in regulations) is used on an ongoing basis by your plant [26]. *

V44: Information about best-in-class environmental performance is tracked and recorded by your plant [26].

V45: Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis [26].

V46: Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications [26]. *

V47: Cost accounting has been used extensively by your plant for capturing and reporting environmental problems and costs [26]. *

Factor 8 (F8)—ERM results: ERM results are defined as the organization's improvements in ERM [36], [107]. The quantifiable measures for the ERM results factor were introduced by: "Please estimate the magnitude of change experienced in each environmental measure over the last three years:" These measures were 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.)

APPENDIX B
DATA ANAYLSIS

A two-wave mailing, with reminder postcards sent in between, employing many of the techniques developed by Dillman [44], resulted in returns of 269 and 257 usable surveys from the first (group 1) and second (group 2) wave of responses, respectively. This yielded a combined and overall response rate of 17.86%. Descriptive statistics of the survey respondents for groups 1 and 2 are provided in Table III.

A. Assessment of Measurement Model Fit

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. The purpose was to ensure unidimensionality of the multiple-item constructs and to eliminate unreliable items from them. While the results of the CFA guide the direction of this paper, an exploratory factor analysis (EFA) was also performed and these results have been provided in Appendix B.

The four factors were combined into a structural equation model for CFA with explicit estimation of the correlation between factors. The estimation of parameters in the model was determined using maximum likelihood (ML) estimation [16], [22], [83]. The applications of structural equation modeling within this study were executed using the EQS/Windows program [16]. Overall fit was assessed using five statistics: χ^2, χ^2/df, normed fit index (NFI), nonnormed fit index (NNFI) [17], and the comparative fit index (CFI) [15]. A small value of χ^2 relative to the degrees of freedom (which should be less than 3) signifies that the observed and estimated matrices do not differ considerably. NFI, NNFI, and CFI provide measures of complete covariation in the data, with a value greater than 0.90 indicating acceptable fit to the data. Furthermore, no indications of departures from normality existed.

B. Testing the Hypothesized Measurement Models

Presented with initial 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

TABLE III
RESPONDENT DATA

Group 1 Respondents (n=269)

	Mean	Standard Deviation	Median	Minimum	Maximum
Respondent's Experience in Current Position (Years)[a]:	5.9	5.19	4	0.7	30
Number of Employees[b]:	309.3	297.80	221	15	1,975
Plant Size (Square Feet)[c]:	171,464.6	184,711.98	120,000	10,000	1,500,000
1995 Sales Volume ($)[d]:	53,997,726.3	66,497,170.36	35,000,000	1,000,000	640,000,000
1996 Sales Volume ($)[e]:	61,764,063.3	76,658,230.06	40,000,000	1,000,000	690,000,000
Average Age of Production Equipment (Years)[f]:	10.1	7.20	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 (42.0%); Held Other Title (e.g., V.P., President, C.E.O, G.M., etc.): 152 (56.5%); No responses to title: 4 (1.5%)

Union Representation: 93 (34.6%); Non-Union Representation: 176 (65.4%)

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)

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.

Group 2 Respondents (n=257)

	Mean	Standard Deviation	Median	Minimum	Maximum
Respondent's Experience in Current Position (Years)[a]:	6.1	5.71	4	0.5	40
Number of Employees[b]:	362.7	456.28	235	24	3,500
Plant Size (Square Feet)[c]:	184,578.4	240,612.39	115,000	13,000	2,000,000
1995 Sales Volume ($)[d]:	60,511,771.7	101,559,088.40	30,000,000	1,000,000	1,076,593,000
1996 Sales Volume ($)[e]:	67,409,102.4	104,760,507.60	32,000,000	1,800,000	998,789,000
Average Age of Production Equipment (Years)[f]:	11.0	8.43	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 (37.4%); Held Other Title (e.g., V.P., President, C.E.O, G.M., etc.): 160 (62.3%); No Responses to Title: 1 (.3%)

Union Representation: 82 (31.9%); Non-Union Representation: 175 (68.1%)

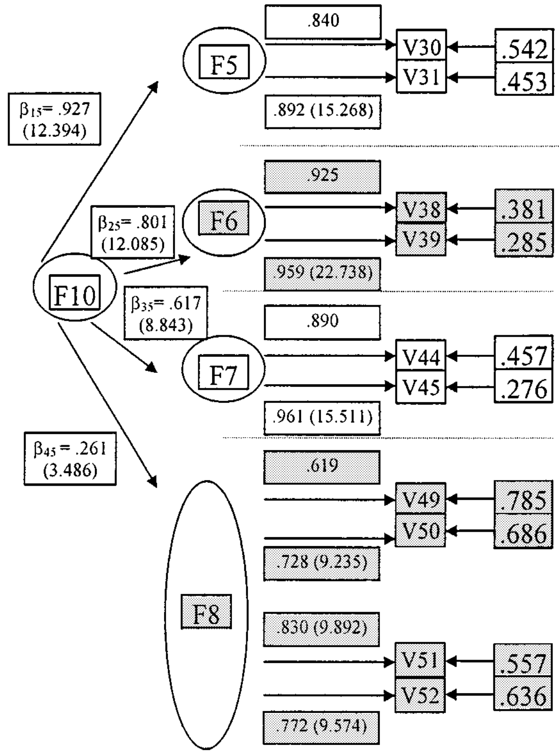
Number of Plants by Region: Michigan (36); Ohio (18); Illinois (17); Indiana (14); Tennessee (11); Kentucky (10); Pennsylvania (5); Virginia (5); Wisconsin (4); Georgia (3); Massachusetts (3); North Carolina (3); California (2); Florida (2); Iowa (2); Minnesota (2); Missouri (2); New York (2); Texas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

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 [22], [25].

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). As recommended, only one parameter was changed at every step [83]. 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. The fit of the models were satisfactory based on all five fit criteria.

Very few researchers have actually illustrated any known instability and problematic nature of estimated constructs defined by two indicators. Single-item measures would have been problematic because it is not possible to empirically estimate the reliability; however, we have at least two measures for each factor. Unidimensionality can still be assessed with external consistency when there are only two indicators [6]. Several other re-



* Each first-order factor has a disturbance term associated with it. D5=.375, D6=.599, D7=.787, and D8=.965.
( ) t-values in parentheses

Goodness-of-Fit Indices

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

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

Fig. 3. The final full TQM CFA measurement model.

searchers have also stated that latent variables can be measured with only two indicators since all key psychometric properties can still be assessed [29], [31], [77], [108], [133].

The revised models were tenable from a content and theoretical standpoint. In addition, there were no examples of parameters exhibiting unreasonable estimates (e.g., correlations greater than 1.0, negative variances). 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 [38]. 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 [146]. 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 $(p < 0.001)$.

In addition, none of the LM χ^2 values were statistically significant, indicating that there were no significant cross-loadings. This demonstrated discriminant validity. Furthermore, all of the scales had statistically significant and positive correlations with the primary outcome factors of TQM results (F4) and ERM results (F8), respectively. Thus, criterion-related validity was supported for all the scales. Finally, all of the interfactor correlations were positive and significant.

C. Cross-Validation and Nonresponse Bias

This section addresses the issue of nonresponse 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; $n = 257$).

In testing for invariance across both groups, the factor loadings and covariances for each measurement model were tested for their equivalence across groups. 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. Given these findings, we can state that all measures of TQM and ERM operate in the same way for both groups. Some 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 [7].

D. Relationships Among the First-Order Factors

Nomological validity was assessed from the final measurement models using the interfactor correlations [12]. All correlations were statistically significant and positive, with some of the correlations being very large. 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.

E. Second-Order CFA Models

The TQM and ERM factor analytic models presented to this point have used four factors that operated as independent variables. However, theory, as captured in Fig. 1, argues for a higher level factor that is considered accountable for the lower-order factors. This model essentially has the same first-order factor structure. However, the 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. 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.

The overall model statistics indicate that the fit of the second-order models are as good as that of the first-order models (see Figs. 2 and 3). The results presented in these figures show that the loadings of all four first-order factors on the second-order factors are positive and significant.

F. The Full Structural Equation Model

Having established the various measurement models, we are now ready to proceed to the larger and more comprehensive structural model. This model, diagrammed in Fig. 1, consists of both the measurement models and a structural model. The structural component of the model in Fig. 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).

G. Testing the Full Structural Equation Model

In the previous section, it was found that the two waves of respondents could be considered to be equivalent. As a result, the group data can be pooled and all subsequent investigative work can be based on a single-group analysis [25], [82]. This pooled group consists of 531 returned questionnaire responses, yielding a response rate of 18.03%. However, five of the questionnaires were unusable. Thus, the effective response rate was 17.86% (526 responses).

Estimation of the full SEM model resulted in an overall $\chi^2_{(221)}$ value of 632.093, with a CFI value of 0.938. Turning first to these goodness-of-fit statistics, it is concluded that there is a high degree of fit in the model. Considering the excellent fit of the model to the data and the small magnitude and atheoreticalness of the LM χ^2 statistics, no further additions to the model were required.

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. Examining the test statistics associated with the structural estimates, it can be seen that all are significant. Furthermore, the Wald test did not identify any parameters as being redundant, indicating that none of the free parameters were dropped in the process [16].

H. Testing the Structures Between TQM and ERM

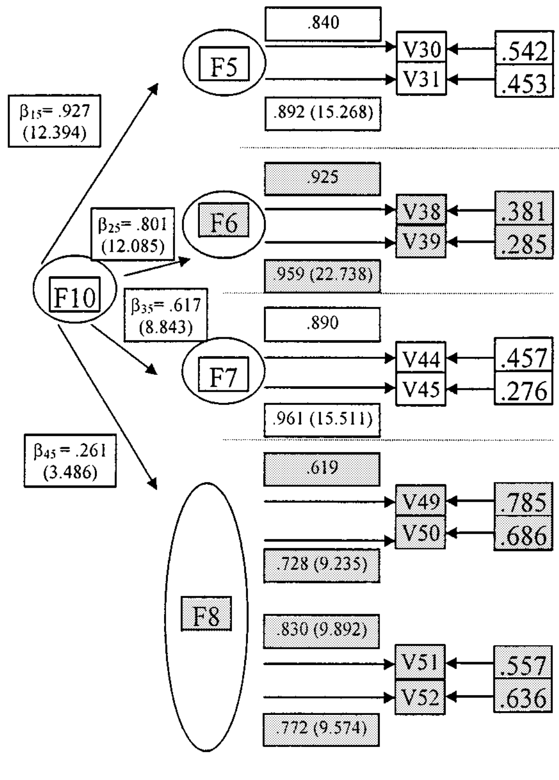
The research problem addressed by this study is that the structures associated with TQM- and ERM-based systems are very similar. Therefore, the structures between TQM- and ERM-based systems can be hypothesized to parallel one another. This perspective is reflected in the following research hypotheses:

$$\begin{aligned}\beta_1 - \beta_5 &= 0, \quad p < 0.05\\ \beta_2 - \beta_6 &= 0, \quad p < 0.05\\ \beta_3 - \beta_7 &= 0, \quad p < 0.05\\ \beta_4 - \beta_8 &= 0, \quad p < 0.05.\end{aligned}$$

These hypotheses were assessed by imposing equality constraints on the estimated parameters within the same sample. Turning to the univariate LM χ^2 statistics and related probability values associated with each quality constraint, it was found that only the fourth constraint was invariant across both TQM- and ERM-based systems. The univariate and multivariate analyzes for the first three constraints reflected the noninvariance of the parallel structural paths across the TQM- and ERM-based systems. In other words, there is no reason to believe that the structures associated with TQM- and ERM-based systems are different.

APPENDIX C
RESULTS OF THE EXPLORATORY FACTOR ANALYSIS

The data obtained would be subjected to confirmatory factor analysis (CFA) as opposed to exploratory factor analysis (EFA). Since this was also a measurement paper, the following minimal subset was considered important for assessing the measurement properties of a construct: unidimensionality and convergent validity, discriminant validity, criterion-related validity, nomological validity, and reliability. An EFA is based on "rules of thumb" rather than statistical tests and it can only assess convergent validity. A CFA is based on statistical tests in which all the key psychometric properties can be assessed. Therefore, a CFA seemed better suited for a paper whose major contribution is the development of scales. The CFA approach is most often used to test instrument validation and modify instruments for better psychometric properties.



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** Distribution of standardized residuals was symmetric and centered on zero.

Fig. 4. The final full ERM CFA measurement model.

Finally, the reason for structural equation modeling's attractiveness was twofold: 1) it provided a straightforward method of dealing with multiple relationships simultaneously while providing statistical efficiency and 2) its ability to assess the relationships comprehensively provided a transition from exploratory to confirmatory analysis. This transition will hopefully correspond to a greater effort in the ERM field toward developing a more systematic and holistic view. However, such efforts will require the ability to test a series of relationships constituting a large-scale model. This is a task for which SEM is well-suited. Moreover, SEM allows for a statistical test of the goodness-of-fit for the proposed confirmatory factor solution, which is not possible with factor analysis.

However, we do recognize the exploratory nature of developing a preliminary measurement instrument in an area which has only recently emerged. Mulaik [115] provided several strong arguments in favor of performing a CFA by arguing that the major disadvantage of an EFA lies in the difficulty involved in interpreting factors. The EFA results were indeed very difficult to interpret. Furthermore, the ERM construct was "underfactored" yielding a three factor solution.

ROTATED FACTOR MATRIX

FACTOR :	1	2	3
V44*	0.907		
V45*	0.875		
V46	0.670		
V36	0.632		
V32	0.591		
V39*		0.897	
V38*		0.887	
V34		0.628	
V43		0.605	
V51*			0.851
V52*			0.733
V50*			0.705
V49*			0.646

Extraction Method: Generalized Least Squares
Rotation Method: Equamax with Kaiser Normalization
Rotation converged in 5 iterations

* These measures were retained in the final ERM CFA Measurement Model

Factor 1:

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

V46: Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications

V36: Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant

V32: Employees throughout your plant are evaluated on environmental performance results

Factor 2:

V39*: An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant

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

V34: Adequate resources are provided to carry out environmental improvements within your plant

V43: Environmentally-related information (e.g., changes in regulations) is used on an on-going basis by your plant

Factor 3:

V51*: Volume of hazardous waste

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

V50*: Tons of solid waste landfilled

V49*: Volume of wastewter discharges

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Sime Curkovic is an Assistant Professor of Supply Chain Management at Western Michigan University. He received the undergraduate degree in management systems from GMI Engineering and Management Institute. He received the Ph.D. degree from Michigan State University.

Dr. Curkovic has taught several courses in sourcing, operations, and logistics management. His research interests include environmentally responsible manufacturing, total quality management, supply chain management, and integrated global strategic sourcing. Dr. Curkovic's publications have appeared and/or are under review in the International Journal of Purchasing and Materials Management, the Decision Sciences Journal, and the Journal of Quality Management. His professional memberships include ASQ, APICS, DSI, INFORMS, NAPM, and POMS. Dr. Curkovic's previous work experiences were with General Motors in the midwest, Mexico, and Germany.

Steven A. Melnyk was educated at the University of Western Ontario (London, Ontario, Canada), where he received his doctorate in operations management in 1981. Currently, he is a Professor of Operations Management at Michigan State University, where he has taught since 1980. He has co-authored over ten books and major research monographs and he has published extensively in such journals as the International Journal of Production Research, the Journal of Operations Management, Production and Operations Management Journal, Production and Inventory Management, the Journal of Supply Chain Management, Business Horizons, and the International Journal of Production and Operations Management. In addition, he has just completed a major research project into Environmental Responsible Manufacturing that was funded by the National Science Foundation. His current research interests include environmentally responsible management, metrics and system measurement, and time based competition. Finally, Steven A. Melnyk has served as a consultant for over 60 firms. He is also the Software Editor for the APICS and lead author of the "Back to Basics" column that appears every month in APICS: The Performance Advantage.

Robert B. Handfield is the Bank of America Distinguished University Professor of Supply Chain Management in the College of Management at North Carolina State University. He was educated at the University of North Carolina at Chapel Hill and received a doctorate in operations management in 1990. His research focuses on interviews with managers deploying supply chain management, environmental and new product development strategies. He is also the Director of the Supply Chain Management Resource Center at North Carolina State University.

Roger Calantone is the Eli Broad Professor of Marketing and Product Innovation, Eli Broad Graduate School of Management, Michigan State University. He currently teaches and researches in the areas of new product development, biomedical product design & testing, and international marketing. He has written several articles for marketing, operations and engineering journals and serves on the editorial board of the *Journal of Marketing*.