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# Environmentally Responsible Manufacturing: The development and validation of a measurement model

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**Abstract**

The concept of Environmentally Responsible Manufacturing (ERM) is relatively new and it is not surprising to note the lack of theory-based, empirically validated constructs and measures. Such constructs and measures are critical to the development and growth of rigorous research in this area. This paper develops and assesses such constructs and measures. Drawn from an exhaustive review of both the quality and ERM-related fields, this study uses the constructs and measures drawn from the Total Quality Management area to develop ERM-related constructs and measures. These are then evaluated using data from a survey of 526 plant managers in the US automotive industry. The resulting models, constructs, and measures are then studied using confirmatory factor analysis and structural equation modeling. The results show the presence of an ERM framework and the presence of the underlying latent and manifest variables. The findings provide an important foundation to others interested in doing future research in this area.


*Keywords:* Environmentally Responsible Manufacturing; Total Quality Management; Survey research; Confirmatory factor analysis; Structural equation modeling

## 1. Introduction

Environmentally Responsible Manufacturing (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 (Curkovic and Landeros, 2000; Handfield et al., 1997; Melnyk et al., 2001). Fundamental to ERM is the recognition that pollution, irrespective of its type and form, is waste. Strategies such as Just-In-Time (JIT), Total Quality Management (TQM), and Time Based Competition (TBC), have defined waste as 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, 1995). 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 (Hanna et al., 2000). It would be expected that more managers be interested in the development and use of ERM based systems. However, for most firms, ERM has not

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achieved the same degree of acceptance as have JIT, TQM, and TBC (Angell and Klassen, 1999; Epstein, 1996; Makower, 1993, 1994).

ERM theory is far from being fully developed (Daniel et al., 1997; Klassen, 1995; Klassen and Angell, 1998; Post and Altman, 1992; ReVelle, 2000). It is critical that researchers link theoretical concepts such as ERM to empirical indicants (i.e., measures). This will allow the field to move from anecdotes and case studies, the current focus of most ERM research, to testable models and hypotheses. The ERM field currently lacks many of these theoretically derived and empirically tested measures. It is virtually impossible to encourage the development, construction, and continued refinement of theory without such measures (Bagozzi, 1981; Klassen, 2000a,b; Peter, 1981; Venkatraman, 1989). The primary objective of this paper is to develop and empirically validate constructs, measures, and scales central to the concept of ERM. Specifically this paper will

- Develop an operational framework of ERM that is theoretically grounded.
- Identify major constructs, measures, and scales associated with this framework.
- Empirically validate these scales.
- Assess the implications of the findings for ERM research.
- Provide recommendations for future extensions of this research.

The assessment and validation of the measurement model and the associated scales is done using confirmatory factor analysis (CFA) and the structural equation modeling (SEM) approach. This paper begins by defining ERM and identifying its associated constructs. A review of the appropriate body of literature is required to do this.

## 2. A review of the ERM literature

Learning about ERM by reviewing the literature is a difficult task because of the diversity of sources contributing to its development and growth. Greater attention was given to the articles appearing in the refereed journals because of the rigorous reviewing process. The search was restricted to papers published primarily after 1980. Based on this review, three categories of frameworks emerged: (1) anecdotal; (2) empirically based research; and (3) formal assessment processes.

The first category deals with corporate success stories and the personal experiences of people involved in the implementation and development of ERM systems and practices (e.g., Cairncross, 1992; Epstein, 1996; Makower, 1993, 1994). While being the largest category in terms of the number of papers published, the anecdotal category is of limited importance since it is very difficult to generalize the resulting prescriptions.

The empirically based research category looks at applied studies that mostly chart a continuum of corporate approaches toward ERM. This research has suggested two perspectives on patterns of ERM: (1) a strategic perspective (Arnfalk and Thidell, 1992; Dillon and Fischer, 1992; Handfield et al., 1997; Klassen, 1995; Logsdon, 1985; Mahon, 1983; Miles, 1987; Sarkis, 1998; Schot, 1991; Vastag et al., 1996); and (2) a developmental progression (Clarkson, 1991; Dyckhoff and Allen, 2001; Epstein, 1996; Flannery and May, 1994; Greening, 1992; Hunt and Auster, 1990; Marguglio, 1991; Petulla, 1987; Post and Altman, 1992; ReVelle, 2000). The strategic perspective implies that distinct choices are made among a set of alternatives, while a developmental progression proposes managed expansion or growth over time (Klassen, 1995, 2000b). The research literature is clearly divided on whether distinct strategies are used or whether firms evolve through a progression of stages. Logsdon (1985) and Klassen (1995) both point out that the lack of a definitive answer is due in part to very few large-scale empirical studies. Most of these continuum studies conclude that the majority of firms are in transition between different phases, generally moving away from reactive toward proactive strategies.

All of these applied studies have helped identify positive traits of ERM firms, but few have attempted to determine causal relationships (e.g., with ERM performance and management methods). Klassen (1995, 2000a,b), Vastag et al. (1996), Sarkis (1998), and Dyckhoff and Allen (2001) were among those to have actually undertaken hypothesis generation and theory testing. Furthermore, none of the applied studies presented instruments for measuring the effectiveness of the underlying ERM constructs. It appears that the ERM applications have preceded the theoretical framework.

The third and final category from the literature examined popular formal assessment processes developed by such external organizations as the International Standards Organization (ISO), the Global Environmental Management Initiative (GEMI), and the Council of Great Lakes Industries (CGLI). While important to international and national assessment processes, this category does not lend itself to well-developed and empirically validated measurement instruments.

These three categories of frameworks were used in an attempt to identify the various views of ERM in terms of its impact on strategic planning and organizational deployment. However, a review of the ERM literature reveals the need for well-developed, reliable, and valid measures for important dimensions of ERM within an organization-wide context. Such a system of measures is a prerequisite for ERM theory building, and this study focuses on creating a preliminary instrument for assessing an organization's extent of deployment of ERM practices. The ERM literature is not at a level of development necessary for a more rigorous evaluation and formulation of ERM constructs and issues. As a result, it was necessary to look outside of the ERM field to develop an operational framework of ERM.

## 3. Developing an operational framework of ERM

After reviewing several other fields, it was decided to focus on the similarities between TQM and ERM. This decision was based on the observed parallels between TQM and ERM based systems noted by numerous researchers (e.g., Alm, 1992; Corbett and Cutler, 2000; Curkovic and Landeros, 2000; Epstein, 1996; Friedman, 1992; Green, 1993; Habicht, 1991; Hanna and Newman, 1995; Hart, 1995; Klassen and McLaughlin, 1993; Klassen and Whybark, 1999a,b; Makower, 1993; May and Flannery, 1995; McInerney and White, 1995; Neidart, 1993; Puri, 1996; Rondinelli and Berry, 1997; Sarkis and Rasheed, 1995; Shrivastava, 1995; Theyel, 2000; Thompson and Rauck, 1993; Welford, 1992; Wheeler, 1992; Willig, 1994; Woods, 1993). 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; and (7) demand continual self-assessment and improvement. 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.

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 (Curkovic and Handfield, 1996; Evans, 1997). 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 (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, while Capon et al. (1995) used it to identify measures of TQM success (also see, Choi and Eboch, 1997; Curkovic and Handfield, 1996; Dew, 1994; George and Weimerskirch, 1994). Curkovic et al. (2000a,b) also empirically assess the assumption that the MBNQA framework adequately captures the major dimensions of TQM. The results show empirically that the MBNQA framework does capture the concept of TQM. Furthermore, Handfield and Ghosh (1994) studied the nature of the interdisciplinary linkages among approach/deployment and results categories of the MBNQA criteria. The results empirically validate the model implicit in the criteria.

In cross-fertilization attempts, which is 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.

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., McGee and Bhushan, 1993; Corbett and Cutler, 2000; Curkovic and Landeros, 2000) 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. Although the MBNQA annually recognizes US 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.

### 3.1. 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. Since the MBNQA framework is the most consistent with the definition of TQM and is often used as the operational framework of TQM, the seven categories associated with the framework will be used to draw parallels between TQM and ERM. Parallels are drawn to further reinforce 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 1.

## 4. The 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: (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 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; and (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).

## 5. Research design

### 5.1. Data collection

Prior studies of ERM consist largely of case studies (Arthur D. Little, 1989; Logsdon, 1985; Mahon, 1983; Marguglio, 1991; Miles, 1987; Post and Altman, 1992; Schot, 1991; 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. 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 required for making comparisons, can be used across a broad population in order to make generalizable conclusions

Table 1
Drawing parallels between TQM and ERM

*Leadership*
• Senior management acts as a driver for TQM implementation (Juran, 1978, 1981a,b; Ham and Williams, 1986; Kennedy, 1989; Tregoe, 1983)
• The critical guide and motivator for the development and implementation of ERM must also come from senior management (Arthur D. Little, 1989; Bemowski, 1991; Egri and Herman, 2000; Epstein, 1996; Hunt and Auster, 1990; Makower, 1993; Schot, 1991; Wever and Vorhauer, 1993)

*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 (Dale and Duncalf, 1985; Garvin, 1987; Juran, 1978; Wheelwright, 1981)
• 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 (Corbett and Cutler, 2000; Herod, 1989; Hunt and Auster, 1990; Epstein, 1996; Klassen and McLaughlin, 1993; Wever and Vorhauer, 1993)

*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 (Baum, 1990; Feldman, 1991; Ishikawa, 1985; Juran and Gryna, 1988; Lascelles and Dale, 1989a)
• ERM also requires the adoption of response systems to handle the most basic of customer/stakeholder concerns or requirements (CGLI, 1994; GEMI, 1996; Johannson, 1993)

*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 (Babbar, 1992; Garvin, 1983; Riehl, 1988; Willborn, 1986)
• ERM also requires extensive information collection and analysis and the latest technology for managing information resources (Bracken, 1985; CGLI, 1994; Fitzgerald, 1994; Johannson, 1993; Orlin et al., 1993)

*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 (Cole, 1980; Ebrahimpour, 1985; Harber et al., 1993a; Juran, 1981a,b; Lee and Ebrahimpour, 1985; Longnecker and Scazzero, 1993; Oliver, 1988)
• The best results from ERM also can be only obtained when there is a high level of involvement and commitment from trained people (Cook and Seith, 1991, 1992; Cramer and Roes, 1993; Hanna et al., 2000; Enander and Pannullo, 1990; Geffen and Rothenberg, 2000; Gripman, 1991; Gupta and Sharma, 1996; Marguglio, 1991; May and Flannery, 1995; Wever and Vorhauer, 1993)

*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 (Benton, 1991; Bhote, 1989; Garvin, 1983, 1987; Juran and Gryna, 1988; Modarress and Ansari, 1987; Stein, 1991; Taguchi and Clausing, 1990)
• 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 (Blacker and Fratoni, 1990; May and Flannery, 1995; Geffen and Rothenberg, 2000; Klassen and McLaughlin, 1993; Van Weenen and Eeckels, 1989; Wever and Vorhauer, 1993)

*Business results*
• TQM requires that companies monitor and improve their quality performance based on objective measures of quality and operational results (Cole, 1990; Fisher, 1992; Fortuin, 1988; Reddy and Berger, 1983)
• Whenever ERM is implemented, measures should be identified to determine if the systems is delivering the desired results (CGLI, 1994; GEMI, 1996; McGee and Bhushan, 1993; Theyel, 2000)

(Fowler, 1998). For the purposes of this study, a survey was used. The reason for this is that very few empirical studies have undertaken broader scale investigations to empirically test hypotheses associated with ERM (Dillon and Fischer, 1992; Klassen, 1993, 1995, 2000a,b; ReVelle, 2000). Empirical research in this direction will be required if ERM is to be transformed into a rationally and formally evaluated discipline.

An investigation of the underlying constructs was undertaken using a two-phase approach: (1) preliminary scale development was conducted using interviews from managers to provide assistance in the identification and prima facie validation of the constructs and variables in the study; and (2) implementation of a large-scale survey designed to validate scales for measuring the underlying constructs associated with ERM. This combination allowed for the exploitation of the strengths of both case studies and surveys while reducing the problems associated with each.

### 5.2. The sample

A single industry was chosen for the study. 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 would not provide a strong basis for external generalizability. To empirically test a model dealing with ERM, an ideal industry should possess two primary characteristics (Klassen, 1995): (1) a high degree of variation in ERM programs; and (2) a competitive marketplace. Furthermore, an ideal industry to test an ERM measurement instrument is one in which significant, new environmental regulation is under development or in its early stages of implementation (Klassen, 1995; Logsdon, 1985; 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 criteria, the automotive industry was chosen. More specifically, the sample was targeted across a specific 4-digit SIC code within the automotive industry – Motor Vehicle Parts and Accessories (SIC 3714). Standard Industrial Code (SIC) is a US government industry identification number. This code is used for tracking the number of businesses in different industrial categories. An updated and comprehensive database of 2945 manufacturing facilities within this SIC code was obtained from Elm International (an automotive industry consulting firm located in East Lansing, MI). 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. The major environmental issue facing the industry includes the implementation of amendments to the Clean Air Act of 1990, along with other waste concerns (Geffen and Rothenberg, 2000; Handfield et al., 1997; Klassen, 1995, 2000a,b). Individual plants within the industry are pursuing a variety of environmental strategies, and apparently with mixed results. 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 (Logsdon, 1985; Shelton, 1995).

### 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. Many investment options (e.g., environmental technologies), are identified at the plant level, either by operating personnel, external consultants, or corporate specialists. As mentioned by Klassen (1995), Klassen and Whybark (1999a,b), and Shelton (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.

### 5.4. Sample selection

Miller and Roth (1994) suggest that greater attention to informant selection can help to overcome the common method variance problem when practical considerations require single respondents. Phillips (1981) argued that the selection of appropriate respondents depends on what you want to know, but also that high-ranking respondents tend to be more reliable sources of information than their lower ranking counterparts. Ideally, information should be gathered from multiple respondents at each site to minimize the potential for bias from a single respondent (Klassen and McLaughlin, 1996). For example, having access to a quality, environmental, and plant manager for each site would minimize monorespondent bias. However, the cost and time associated with obtaining access to multiple individuals at each site and from large numbers of large sized plants in a specific SIC code was 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 actually suffer from the problem of social desirability. 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.

## 6. Data analysis

The hypothesized overall model is portrayed in Fig. 1 in EQS notation. It represents a typical covariance structure model. The single-headed arrows leading from the second-order factor of ERM (F5) to each of its underlying first-order factors (F1,F5; F2,F5; F3,F5; F4,F5) are regression paths that indicate the prediction of ERM Strategic Systems (F1), ERM Operational Systems (F2), ERM Information Systems (F3), and ERM Results (F4) 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). These represent residual errors in the prediction of the first-order factors from the higher-order factor of ERM.

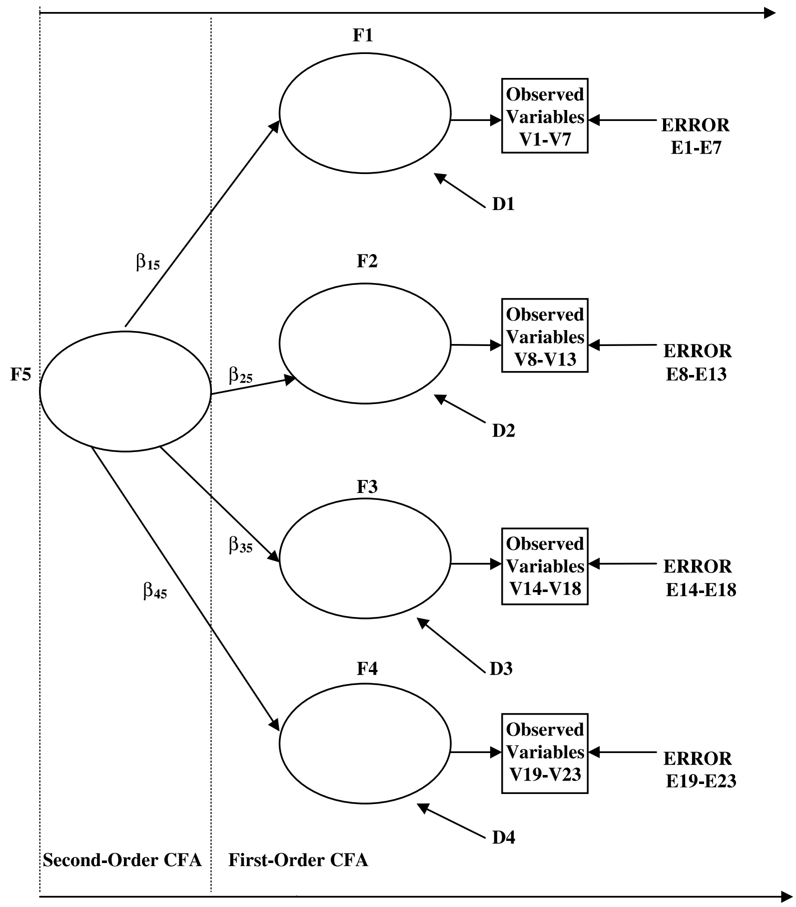
One important omission in Fig. 1 is the presence of double-headed arrows among the first-order factors thereby indicating their intercorrelation. This is because the development and validation of the ERM measurement models progresses from the first- to second-order factors. This iterative process will help to indicate that all covariation among the first-order factors is explained by the second-order factor (Anderson and Gerbing, 1988; Joreskog and Sorbom, 1993).

Expressed more formally, the CFA model portrayed in Fig. 1 hypothesizes a priori that: (1) 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 will be correlated; and (5) covariation among the four first-order factors will be explained fully by their regression onto the second-order factor.

### 6.1. Confirmatory versus exploratory factor analysis

The data will be analyzed with confirmatory factor analysis (CFA) as opposed to exploratory factor analysis (EFA). Since this was 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 (Mulaik, 1972; Bentler, 1992a). The CFA approach is most often used to test instrument validation and modify instruments for better psychometric properties (Anderson and Gerbing, 1988; Bollen, 1989; Venkatraman, 1989; Byrne, 1988).

Finally, the reason for structural equation modeling's attractiveness was two-fold: (1) it pro-




F5 = Factor 5 = ERM (2nd Order Factor)
F1 = Factor 1 = ERM Strategic Systems (1st Order Factor)
F2 = Factor 2 = ERM Operational Systems (1st Order Factor)
F3 = Factor 3 = ERM Information Systems (1st Order Factor)
F4 = Factor 4 = ERM Results (1st Order Factor)

Fig. 1. ERM measurement model.

vided 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 principal components/factor analysis.

However, the exploratory nature of developing a preliminary measurement instrument in an area which has only recently emerged is recognized. While the results of the CFA guide the direction of this paper, an EFA was also performed and these results are available to the reader in Appendix B. Mulaik (1972) 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.

### 6.2. Data collection

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 (Group 1) and second (Group 2) wave of responses, respectively. This yielded a combined and overall response rate of 17.86%. This number is very consistent with response rates associated with strategy research, and is a very high number for environmental research (due to sensitivity issues). Statistical conclusion validity would have been a potential problem if the power were not high enough. Churchill (1979) note that when the sample size is small it is dangerous to rely solely on statistical significance. However, with 2945 plants being targeted, and only around 30 parameters in the model being estimated, a 5–10% response rate would have provided the statistical power required. This study has a much larger sample size. Descriptive statistics of the survey respondents for Groups 1 and 2 are provided in Table 2.

### 6.3. Assessment of measurement model fit

The development and validation of the measurement model was conducted using responses from only the first wave of surveys received. Once the measurement model was 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 was performed. This test will determine whether the factorial structure of the measurement model replicates 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 and Sorbom, 1993). Meaning, a test of the overall SEM will be conducted using responses from both waves.

Tests of hypotheses related to group invariance begins and ends with scrutiny of the ERM measurement model. Invariance at the overall SEM level will exist if invariance in the measurement model can be demonstrated (Byrne, 1988; Joreskog and Sorbom, 1993). In particular, the factor loadings and covariances for the measurement model were tested for its equivalence across groups. The EQS approach tests the validity of equality constraints multivariately rather than univariately, using the Lagrangian Multiplier (LM) test. All equality constraints could be put to the test simultaneously.

From an operational perspective, the following minimal subset was considered important for assessing the measurement properties of a construct (Klassen, 1995; Peter, 1981; Venkatraman, 1989): unidimensionality and convergent validity, discriminant validity, criterion-related validity, nomological validity, and reliability. The measurement properties of ERM were first assessed by testing the initially hypothesized full first-order ERM measurement model using confirmatory factor analysis (CFA). A strong a priori basis for the hypothesized four factor ERM measurement model 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.

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 (Bentler, 1989, 1992a; Bollen, 1989; Joreskog and Sorbom, 1993). The applications were executed using the EQS/Windows program.

According to Anderson and Gerbing (1988), a fundamental distinction can be made between the use of structural equation modeling (SEM) for theory testing and development versus predictive application. For clarity, they characterize this choice as one between a full-information (ML) estimation approach and a partial least squares

Table 2
Respondent data

| | Mean | Standard deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| *Group 1 respondents* ($n = 269$) | | | | | |
| 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] | 171464.6 | 184711.98 | 120,000 | 10,000 | 1,500,000 |
| 1995 Sales volume ($)[d] | 53997726.3 | 66497170.36 | 35,000,000 | 1,000,000 | 640,000,000 |
| 1996 Sales volume ($)[e] | 61764063.3 | 76658230.06 | 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

| | Mean | Standard deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| *Group 2 respondents* ($n = 257$) | | | | | |
| 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] | 184578.4 | 240612.39 | 115,000 | 13,000 | 2,000,000 |
| 1995 Sales volume ($)[d] | 60511771.7 | 101559088.40 | 30,000,000 | 1,000,000 | 1,076,593,000 |
| 1996 Sales volume ($)[e] | 67409102.4 | 104760507.60 | 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

(PLS) estimation approach. These two approaches to SEM can be thought of as a complementary choice that depends on the purpose of the research: (1) ML for theory testing and development (this study) and PLS for application and prediction. Drawing on this distinction, a confirmatory approach to theory testing and development using ML methods was used.

One of the more widely used statistics for overall fit is the $\chi^2$ statistic. In large samples, the $\chi^2$ statistic will almost always be significant, since $\chi^2$ is a direct function of sample size (Hartwick and Barki, 1994). As a result, a number of researchers (e.g., Byrne, 1994; Chau, 1997; Hartwick and Barki, 1994; Sethi and King, 1994; Wheaton et al., 1977) use a related measure, $\chi^2$ divided by its degrees of freedom (df), and $\chi^2/\text{df}$ should be less than 3.

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, 1990), 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). Although these three indices of fit are provided in the EQS output, Bentler (1992b) recommends the NFI and CFI to be the indices of choice. Each provides a measure of complete covariation in the data, with a value greater than 0.90 indicating an acceptable fit to the data.

### 6.4. Testing the hypothesized measurement model

A summary of selected fit indices for the EQS analysis is provided in Table 3. Presented with findings of $\chi^2_{(224)} = 948.93$ and CFI = 0.82 for the first-order ERM CFA model, further modification was needed to improve model fit to acceptable levels (e.g., CFI > 0.90). 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).

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 model 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 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).

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 ERM CFA model, consisting of 10 measures was reestimated (see Table 3). The fit of the model is satisfactory based

Table 3
Goodness-of-fit indices

| | |
|---|---|
| *Goodness-of-fit indices for the initially hypothesized first-order ERM CFA model* | |
| $n$ | 269 (Group 1: first wave of responses) |
| Number of latent variables | 4 |
| Total number of observed variables | 23 |
| Degrees of freedom (df) | 224 |
| $\chi^2$ Statistic | 948.93 |
| $p$-Value | 0.001 |
| $\chi^2$/df | 4.24 |
| Bentler–Bonett normed fit index | 0.77 |
| Bentler–Bonett nonnormed fit index | 0.79 |
| Comparative fit index | 0.82 |
| *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 |
| $\chi^2$ Statistic | 43.89 |
| $p$-Value | 0.038 |
| $\chi^2$/df | 1.51 |
| Bentler–Bonett normed fit index | 0.97 |
| Bentler–Bonett nonnormed fit index | 0.99 |
| Comparative fit index | 0.99 |
| *All of the standardized residuals were below 0.11 | |
| **Distribution of standardized residuals was symmetric and centered on zero | |
| *Goodness-of-fit indices for the second-order ERM CFA model* | |
| $n$ | 269 (Group 1: first wave responses) |
| $\chi^2$ Statistic | 45.12 |
| Degrees of freedom (df) | 31 |
| $p$-Value | 0.049 |
| $\chi^2$/df | 1.46 |
| Normed fit index | 0.97 |
| Nonnormed fit index | 0.99 |
| Comparative fit index | 0.99 |
| *All of the standardized residuals were below 0.10 | |
| **Distribution of standardized residuals was symmetric and centered on zero | |

on all the criteria of $\chi^2$, $\chi^2/\text{df}$, NFI, NNFI, and CFI.

The revised model surpasses the hypothesized model on all fit criteria which confirms that the modifications were meaningful. There were no examples of parameters exhibiting these types of unreasonable estimates (e.g., correlations greater than 1.0, negative variances). 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 model to the data (see Table 4).

Having constructs with only two measures should not be considered problematic since few researchers have illustrated any known instability of constructs defined by two indicators. Single-item measures would have been problematic because it is not possible to empirically estimate the reliability; however, there are at least two measures for each factor. Unidimensionality can still be assessed with external consistency when there are only two indicators (Anderson et al., 1987). Several other researchers have also stated that latent variables can be measured with only two indicators since all key psychometric properties can still be assessed (Chau, 1997; Churchill, 1979; Hughes et al., 1986; McHaney and Cronan, 1998; Sethi and King, 1994).

The final model is tenable from a content and theoretical standpoint. Furthermore, the final first-order ERM CFA model satisfied all of the measurement criteria. Cronbach's coefficient $\alpha$ is a widely used measure of scale reliability (Cronbach, 1951; Cronbach and Meehl, 1955). 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 $\alpha$ 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 $\chi^2$ values were statistically significant which means there were no significant cross-loadings, and this demonstrates discriminant validity. Note, that all of the scales also have statistically significant and positive correlations with the primary outcome factor of ERM Results (see Table 5). 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 the next section and the subject of nomological validity.

### 6.5. Relationships among the first-order factors

Nomological validity was assessed from the final measurement model using the inter-factor correlations (Bagozzi, 1981). All correlations were statistically significant and positive, and some of the correlations were very large (see Table 5). 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 ERM.

### 6.6. Second-order CFA model

In the previous ERM factor analytic model, 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 us examine the representation of this model in Fig. 1. This model essentially has the same first-order factor structure. However, in the present example, the higher-order factor, ERM (F5), is hypothesized as accounting for or explaining all variance and covariance related to the first-order factors. As such, ERM is termed the second-order factor. It is important to note that ERM does not have its own set of measured indicators, rather, it is linked indirectly to those measuring the lower-order factors. The first-order factors now operate as dependent variables which means that their variances and covariances are no longer estimated

Table 4
The final first-order ERM CFA model

| | Measurement equation | Standard error | Test statistic ($t$) |
|---|---|---|---|
| *ERM Strategic Systems (F1)* | | | |
| Cronbach's $\alpha = 0.86$ | $V1 = 2.21^{*}F1 + 1.00E1$ | 0.14 | 15.87 |
| | $V2 = 2.45^{*}F1 + 1.00E2$ | 0.14 | 17.26 |
| Standardized solution | $V1 = 0.84^{*}F1 + 0.54E1$ | | |
| | $V2 = 0.89^{*}F1 + 0.45E2$ | | |
| Items dropped: V3, V4, V5, V6, V7 | | | |
| *ERM Operational Systems (F2)* | | | |
| Cronbach's $\alpha = 0.94$ | $V9 = 2.62^{*}F2 + 1.00E9$ | 0.14 | 19.05 |
| | $V10 = 2.64^{*}F2 + 1.00E10$ | 0.13 | 20.21 |
| Standardized solution | $V9 = 0.92^{*}F2 + 0.38E9$ | | |
| | $V10 = 0.96^{*}F2 + 0.28E10$ | | |
| Items dropped: V8, V11, V12, V13 | | | |
| *ERM Information Systems (F3)* | | | |
| Cronbach's $\alpha = 0.92$ | $V15 = 2.65^{*}F3 + 1.00E15$ | 0.16 | 16.69 |
| | $V16 = 2.88^{*}F3 + 1.00E16$ | 0.16 | 18.55 |
| Standardized solution | $V15 = 0.89^{*}F3 + 0.46E15$ | | |
| | $V16 = 0.96^{*}F3 + 0.28E16$ | | |
| Items Dropped: V14, V17, V18 | | | |
| *ERM Results (F4)* | | | |
| Cronbach's $\alpha = 0.825$ | $V20 = 1.15^{*}F4 + 1.00E20$ | 0.11 | 10.39 |
| | $V21 = 1.22^{*}F4 + 1.00E21$ | 0.20 | 12.75 |
| | $V22 = 1.72^{*}F4 + 1.00E22$ | 0.11 | 15.24 |
| | $V23 = 1.40^{*}F4 + 1.00E23$ | 0.10 | 13.81 |
| Standardized solution | $V20 = 0.62^{*}F4 + 0.79E20$ | | |
| | $V21 = 0.73^{*}F4 + 0.69E21$ | | |
| | $V22 = 0.83^{*}F4 + 0.55E22$ | | |
| | $V23 = 0.77^{*}F4 + 0.64E23$ | | |
| Item dropped: V19 | | | |

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

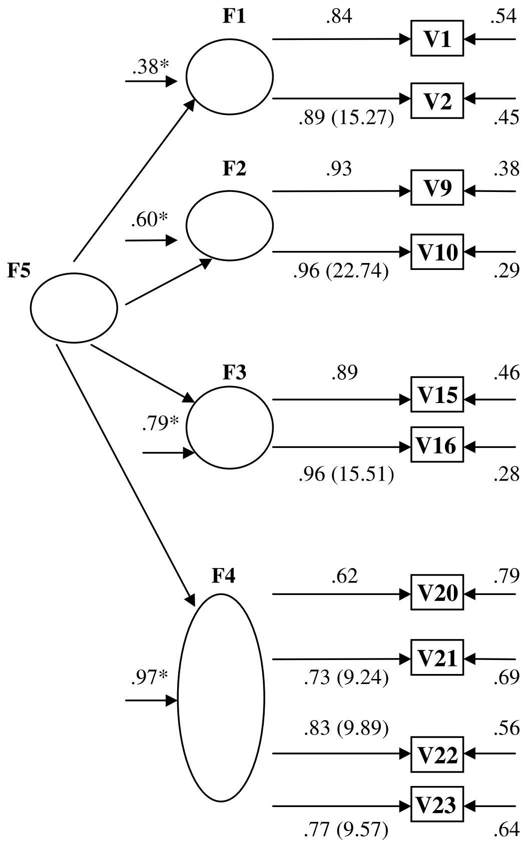
Table 5
Correlations among ERM constructs

| | | | |
|---|---|---|---|
| Factor 1: ERM Strategic Systems<br>Factor 2: ERM Operational Systems | 0. 74[a] | Factor 1: ERM Strategic Systems<br>Factor 3: ERM Information Systems | 0. 57[a] |
| Factor 1: ERM Strategic Systems<br>Factor 4: ERM Results | 0. 27[a] | Factor 2: ERM Operational Systems<br>Factor 3: ERM Information Systems | 0. 50[a] |
| Factor 2: ERM Operational Systems<br>Factor 4: ERM Results | 0. 18[b] | Factor 3: ERM Information Systems<br>Factor 4: ERM Results | 0. 15[b] |

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

parameters in the model. Such variation and covariation is presumed to be accounted for by the higher-order factor (Bentler, 1992a; Byrne, 1988; Joreskog and Sorbom, 1993).

The overall model statistics indicate that the fit of the second-order model is as good as that of the first-order model (see Table 4). This is as it should be, given that the second-order model merely specifies a higher-order factor 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 structure. The results given in Fig. 2, which represents the final full second-order ERM CFA measurement model, shows




* Each first-order factor has a disturbance term associated with it.
( ) t-values in parentheses

$\beta_{15}$ = .93 (12.39); $\beta_{25}$ = .80 (12.09); $\beta_{35}$ = .62 (8.84); $\beta_{45}$ = .26 (3.49)

**F5 = Factor 5 = ERM**

**F1 = Factor 1 = ERM Strategic Systems**
*V1:* Environmental goals are clearly communicated to all plant personnel
*V2:* Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant

**F2 = Factor 2 = ERM Operational Systems**
*V9:* An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant
*V10:* An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant

**F3 = Factor 3 = ERM Information Systems**
*V15:* Information about best-in-class environmental performance is tracked and recorded by your plant
*V16:* Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis

**F4 = Factor 4 = ERM Results**
*V20:* Volume of wastewater discharges
*V21:* Tons of solid waste landfilled
*V22:* Volume of hazardous waste
*V23:* Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur oxides, etc.)

Fig. 2. The final full ERM CFA measurement model.

that the loadings of all four first-order factors on the second-order factor are positive and significant.

### 6.7. Cross-validation and non-response bias

This section deals with determining whether the factorial structure of the ERM CFA model replicates 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, is the ERM CFA model 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, 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 ($F \rightarrow V$); and (2) factor covariances ($F \leftrightarrow F$). Except in particular instances when, for example, it might be of interest to test for the invariant reliability of an assessment of groups, the equality of error variances and covariances is the least important hypothesis to test (Bentler, 1992a; Byrne, 1988; Cudeck and Brown, 1983; Joreskog and Sorbom, 1993).

The results of the test for invariance are presented in Table 6. 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 0.99 for the ERM CFA model, the multigroup models represent excellent fit to the data. The hypothesized equality of the specified factor loadings and covariances held. Given these findings, all measures of ERM are operating in the same way for both groups.

Methods of determining nonresponse bias are often 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 study (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. Evidence of a lack of nonresponse bias exists since the ERM CFA model proved to be equivalent across the first and second wave of responses.

However, it is acknowledged that this cross-validation study only partially addresses the nonresponse issue. Ideally, responding and nonresponding firms would have to be compared with regard to measures such as number of employees or sales totals. One-way ANOVA's could then have been used to show if significant differences existed between the two groups. The mailing procedure did not allow us to distinguish anonymously returned questionnaires from nonrespondents. Therefore, it could not be determined whether the respondent sample was biased towards specific types of firms.

Table 6
Goodness-of-fit indices for the ERM multigroup model

| | |
|---|---|
| Degrees of freedom (df) | 74 |
| $\chi^2$ Statistic | 92.98 |
| $p$-Value | 0.067 |
| $\chi^2$/df | 1.26 |
| Bentler–Bonett normed fit index | 0.97 |
| Bentler–Bonett nonnormed fit index | 0.99 |
| Comparative fit index | 0.99 |

*All of the standardized residuals were below 0.17.

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

## 7. Discussion of results

### 7.1. Assessing the fit between the ERM measures and constructs

In the first set of relationships, the interest was in examining the fit between the measures and the constructs that these were intended to capture. First, the focus is on determining the extent to which there is a unique and theory-driven relationship between measures and constructs. As noted previously, the 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; and (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, it can be said 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, five or more measures were introduced. During the analysis, it was noted that several of the measures were dropped from further consideration.

### 7.2. 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 (Arthur D. Little, 1989; CGLI, 1994; Epstein, 1996; Hunt and Auster, 1990; Makower, 1993, 1994; McGee and Bhushan, 1993; Schot, 1991; Wever and Vorhauer, 1993). This study provides empirical support that senior executives must reinforce ERM values in their organizations.

### 7.3. 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 (Cook and Seith, 1991, 1992; Cramer and Roes, 1993; Hanna et al., 2000; Geffen and Rothenberg, 2000; Green, 1993; Gupta and Sharma, 1996; May and Flannery, 1995; Wever and Vorhauer, 1993). This study provides empirical support that ERM demands that human resource development, in the form of training and development, assume strategic roles.

### 7.4. 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 (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; Makower, 1993, 1994; Orlin et al., 1993). 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.

### 7.5. 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); and (4) tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur dioxides, etc.) (V23). According to Johannson (1993), 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 (Cramer and Roes, 1993; Epstein, 1996; Orlin et al., 1993; Theyel, 2000). 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.

### *7.6. Simplifying the underlying ERM measurement model*

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. 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 10 were retained in the ERM CFA measurement model (ERM Strategic Systems – 2; ERM Operational Systems – 2; ERM Information Systems – 2; and ERM Results – 4).

Simplification is an important goal of any research study. The final ERM model can be viewed as simpler, less complex models. 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. This study has made an attempt to preclude such a situation in the area of ERM. The high dropout rate for items within the four factors resulted from the fact that this research stream is in its early stages and that an important part of what is being contributed is the development of scales. Thus, it was 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 ERM is necessary for future studies to refine the 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 ERM. Regarding the model in Fig. 2 as complete would cause us to ignore numerous important components such as process management, resource allocation, stakeholder views, and many other issues. The model would actually instruct us to only consider issues such as internal communication, training, and benchmarking. This would prescribe a too narrow view of ERM. It therefore becomes necessary for future research to build upon this work. Future research will hopefully identify cases where the dropout rate of items within the factors is significantly lower than in this study. Only then could the ERM factors form the basis of an ERM measure or index. For example, an overall score for each factor could be calculated. A simple sum of item scores might also be adequate. Such an aggregation would have many practical benefits for managers. A profile along the ERM factors would be useful to managers for demonstrating the benefits of an existing ERM based system. Another use could be an evaluation of competitors' usage of ERM. A competitive assessment might reveal reasons for success. The results could form the basis for improvement to current ERM based systems.

### *7.7. Assessing the fit between the MBNQA framework and ERM*

More important and of greater interest, the findings presented in this study draw a unique picture of the ERM *process*. A review of the literature revealed the need for well-developed, reliable, and valid measures for important dimensions of ERM within an organization-wide context. Such a system of measures is a prerequisite for ERM theory building, and this study focused on creating a preliminary instrument for assessing an organization's extent of deployment of ERM. The developmental progression towards ERM is attained by the achievement of certain performance requirements, as captured by these various measures. As these performance traits or measures are attained, the firm is able to achieve the implementation of certain critical 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 ERM system present. In short, it can be argued 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 is provided here are findings based on a cross-section of experiences of firms within a specific industrial sector.

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, Results) of the initially hypothesized ERM CFA measurement model was retained in the final model. In other words, the MBNQA framework was indeed a good predictor 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.

## 8. Further discussion

The ERM measures were a preliminary attempt at operationalizing a higher-order concept 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 this higher-order construct. 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 (Huber and Power, 1985; Phillips, 1981; Sethi and King, 1994). Thus, a logical extension would be to use multiple informants to verify perceptions regarding the features and impact of ERM based systems.

The exact structure of 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 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 ERM by providing a generic framework for implementation. An empirical test of the linkages between the ERM factors can help to provide a roadmap for firms seeking to progress towards environmentally responsible cultures.

## 9. Conclusions

Often in the search for substantive relationships, an emerging field tends to overlook methodological issues such as measurement (Sethi and King, 1994). This study has made an attempt to preclude such a situation in the area of ERM. The high dropout rate for items within the four factors resulted from the fact that this research stream is in its early stages and that an important part of what is being contributed is the development of scales. Thus, it was never expected that all the 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 ERM is necessary for future studies to refine the conceptualization as well as to remove deficiencies in the measures. The intention was to establish the existence of the latent trait ERM more so than its exact structure.

While this study will not create a complete consensus in the field regarding how to measure ERM, it is a constructive move in that direction. Given that reliable and valid measures were needed for ERM constructs, which are in turn important for theory building, this study has developed and validated a preliminary measurement instrument for ERM. By drawing on structural equation modeling (SEM) techniques, this approach provided a more rigorous validation of instruments for unobserved constructs and test of the research model than the classical approach (e.g., exploratory factor analysis). The ability of SEM to assess relationships comprehensively has provided a transition from exploratory to confirmatory analysis (Bollen, 1989). This study has illustrated how this approach can be used to test instrument validation and modify instruments for better psychometric properties.

Furthermore, this research has moved from anecdotes and case studies to a testable model and specific research hypotheses, linking the theoretical concept of ERM to empirical indicants. It has contributed to ERM theory building by identifying the constructs associated with ERM, developing scales for measuring these constructs, and empirically validating the scales. This study has provided the underpinnings for a program of research in the ERM area.

## Appendix A. Operational 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 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 analyses (Cronbach's coefficient alpha). Items which do not have significant $\lambda$s 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).

### *A.1. ERM Strategic Systems (factor 1)*

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 (McGee and Bhushan, 1993; CGLI, 1994; GEMI, 1994; MBNQA, 1997). The questions for the ERM Strategic Systems factor were measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) as follows:

V1 Environmental goals are clearly communicated to all plant personnel (GEMI, 1994).
V2 Environmental responsibility is emphasized through a well-defined set of environmental policies and procedures within your plant (CGLI, 1994; McGee and Bhushan, 1993).
V3 Employees throughout your plant are evaluated on environmental performance results (CGLI, 1994; McGee and Bhushan, 1993).*
V4 Environmental requirements are used to establish a plant level environmental strategy (CGLI, 1994; McGee and Bhushan, 1993).*
V5 Adequate resources are provided to carry out environmental improvements within your plant (CGLI, 1994; McGee and Bhushan, 1993).*

V6 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).*

V7 Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant (CGLI, 1994; McGee and Bhushan, 1993).*

### A.2. ERM Operational Systems (factor 2)

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 (McGee and Bhushan, 1993; CGLI, 1994; MBNQA, 1997). The questions for the ERM Operational Systems factor were measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) as follows:

V8 Human resources management within your plant is affected by environmental plans (CGLI, 1994; McGee and Bhushan, 1993).*

V9 An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant (CGLI, 1994; McGee and Bhushan, 1993).

V10 An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant (CGLI, 1994; McGee and Bhushan, 1993).

V11 Environmental issues are included in the product design process (Calantone et al., 1997).*

V12 Environmental issues are included in the process design process (Calantone et al., 1997).*

V13 Performance on environmental dimensions is considered during supplier evaluations by plant and/or other company personnel (Calantone et al., 1997).*

### A.3. ERM Information Systems (factor 3)

An ERM Information System is defined as the effectiveness of an organization's collection, analysis, and use of information for environmental planning and improvement (McGee and Bhushan, 1993; CGLI, 1994). The questions for the ERM Information Systems factor were measured using an 11-point bipolar scale (e.g., 0 = strongly disagree, 10 = strongly agree) as follows:

V14 Environmentally-related information (e.g., changes in regulations) is used on an ongoing basis by your plant (Calantone et al., 1997).*

V15 Information about best-in-class environmental performance is tracked and recorded by your plant (Calantone et al., 1997).

V16 Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis (Calantone et al., 1997).

V17 Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications (Calantone et al., 1997).*

V18 Cost accounting has been used extensively by your plant for capturing and reporting environmental problems and costs (Calantone et al., 1997).*

### A.4. ERM Results (factor 4)

ERM Results are defined as the organization's improvements in ERM (McGee and Bhushan, 1993; CGLI, 1994). 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 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 >.

V19 Pre/post consumer recyclable content of direct materials (*reversed scale*).*

V20 Volume of wastewater discharges.
V21 Tons of solid waste landfilled.
V22 Volume of hazardous waste.
V23 Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur oxides, etc.).

## Appendix B. Results of the exploratory factor analysis

Rotated factor matrix

| | Factor | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| V15* | *0.907* | | |
| V16* | *0.875* | | |
| V17 | *0.670* | | |
| V7 | *0.632* | | |
| V3 | *0.591* | | |
| V10* | | *0.897* | |
| V9* | | *0.887* | |
| V5 | | *0.628* | |
| V14 | | *0.605* | |
| V22* | | | *0.851* |
| V23* | | | *0.733* |
| V21* | | | *0.705* |
| V20* | | | *0.646* |

*Extraction method*: generalized least squares.
*Rotation method*: equamax with Kaiser normalization.
Rotation converged in five iterations.
* These measures were retained in the final ERM CFA Measurement Model.

*Factor 1* (*best practice*):

V15* Information about best-in-class environmental performance is tracked and recorded by your plant.
V16* Environmental practices, procedures, and systems within your plant are compared with best-in-class on a regular basis.
V17 Environmental achievements of your plant are given prominent visibility within annual reports and other plant and/or company publications.
V7 Measures have been developed to determine the degree of customer/stakeholder satisfaction with the environmental performance of your plant.
V3 Employees throughout your plant are evaluated on environmental performance results.

*Factor 2* (*awareness*):

V10* An adequate amount of training in environmental awareness is provided to managers and supervisors within your plant.
V9* An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within your plant.
V5 Adequate resources are provided to carry out environmental improvements within your plant.
V14 Environmentally-related information (e.g., changes in regulations) is used on an ongoing basis by your plant.

*Factor 3* (*results*):

V22* Volume of hazardous waste.
V23* Tons of hazardous air emissions (CFCs, VOCs, carbon dioxide, methane, sulfur oxides, etc.)
V21* Tons of solid waste landfilled.
V20* Volume of wastewater discharges.

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