Environmental Management Systems: Implications for Operations Management and Performance

Robert Sroufe

Boston College, Wallace E. Carroll School of Management (sroufe@bc.edu)

Abstract

To date, it is unclear as to what an Environmental Management System (EMS) is and how these types of systems impact firm performance. This study reports empirical insights to EMS practices based on the largest EMS survey of firms in the United States to date. Additional field studies support the survey research. The results of this study provide managers with a new and much needed source of information about EMS development and the impact of EMSs on environmental practices and firm performance. Academic colleagues should be interested in this study because it contains an isomorphic model based on industry practices that is empirically tested and contributes to theory development.

1. Introduction

Now more than ever, firms are interested in developing environmental systems and practices. Because of growing environmental regulations, government pressures, international certification standards such as the International Organization of Standards, (ISO) 14000 (Corbett and Kirsch 2001), changing customer demands and managers recognizing pollution as waste (Kleiner 1991; Porter and Van der Linde 1995a, 1995b), firms must now develop environmental policies for their manufacturing plants and supply chain partners while being consistent with new regulations (Rondinelli and Vastag 1996). Consequently, not only researchers, but also manufacturing managers are recognizing the importance of systems used to manage environmental practices. For managers deciding how to tackle environmental issues, however, transforming this recognition into the development of an Environmental Management System (EMS) can be difficult.

The difficulty for managers is compounded by an evolving paradox in the literature. This burgeoning paradox involves a dearth definition of EMSs and the simultaneous growth of importance for this type of systems. One of the only definitions of an EMS is: “the organizational structure, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental management” (ISO 14001 1996). Klassen and Whybark (1999a; 199b) introduced the environmental technology portfolio. A component of this portfolio involves Management Systems. As explained by Klassen and Whybark, these systems are technologies involving infrastructural and integrative investments (Hayes and Wheelwright, 1984; Giffi et. al. 1990) that are part of control and prevention “technologies” and modify operating practices. Technologies (Shrivistava 1995) are used in the general sense of practices that improve housekeeping, reduce material loss, and include environmental measurement systems. Klassen and Whybark go on to say that monitoring environmental performance and compliance audits are also examples of management systems within the environmental technology portfolio (Arthur D. Little, Inc. 1989; Hunt and Auster 1990; Marguglio 1991). The environmental technology portfolio introduces the importance of these “environmental” management systems. The environmental technology portfolio is a good start to understanding some of the attributes of these systems, portfolio does not go far enough to include the more dynamic role of these systems within environmental management and operations.

This study aims to resolve the EMS paradox and further develop one component of the environmental technology portfolio by (1) examining reported environmental business practices (2), developing a more comprehensive definition of an EMS, and (3) gaining an understanding of the relationship between an EMS and the perceived impact of environmental practices on firm performance.

2. Environmental Management Systems

Current practices such as the Ford Motor Company making public statements that all automotive manufacturing operations worldwide will have third party certified EMSs by the year 2003 reveals the importance of these systems for this multinational company (Ford Motor Company 1999). Additionally, Ford and General Motors (GM) are requiring suppliers to have EMS certification (Daniels 2000). The automotive industry actions imply that EMSs have benefits that exceed their costs, but this may be considered an “extreme, or proactive” position by some. Those firms found near the proactive end of the spectrum, include Innovators and Early Adopters of technology initiatives (Moore 1991). These firms tend to be in the minority (Sroufe, Curkovic, Montabon, and Melnyk 2000). Other firms such as 3M, Dow Chemical Corporation, and Herman Miller believe their current EMSs are more advanced than international standards and are taking a “wait and see” approach to EMS certification (Krut and Drummond 1997). Still smaller firms and industries outside the chemical and automotive industry may be the real laggards, or “reactive” in development of efficient and effective EMS. Using the above extreme positions, as the boundaries, there is the need to explore what is happening with the majority of firms and why firms are integrating EMSs.

There are many reasons why EMS should be potentially attractive to firms. First, there is the increasing use of voluntary standards in industry (i.e., ISO 9000, ISO 14000). Second, we see the potential of EMS becoming important to supply chain members (Rondinelli and Vastag 1996). Third, government adoption of EMS standards (Wheeler and Afsah 1996). Fourth, is the potential of EMS to reduce insurance rates (Greenwald, 1997). Fifth, pollution prevention leading to reduced costs of production and higher profits (Dechant and Altman 1994; Makower, 1994; Russo and Fouts 1997; Feldman, Soyka, and Ameer 1997; BSR 1998). Sixth, the increased importance of corporate social responsibility (Wood 1991; Pava and Krausz 1996; Waddock and Graves 1997). Finally, the resource based view of the firm (Barney 1991; Peteraf 1993; Rumelt 1984; Klassen and Whybark 1999b) and the natural resource based view of the firm (Hart 1995; Starik and Rands 1995) have brought attention to the unique environmental resources capabilities and competitive advantage. While the potential benefits are numerous, there is still a dearth of information that defines and empirically tests an EMS construct.

To date, it can be argued that ISO 14000 standards may be the best framework for developing and documenting a structured EMS. For a better understanding of EMS standards we need to consider the following point: existing EMS standards are process not performance standards. These standards do not tell organizations what environmental performance they must achieve aside from compliance with environmental regulation. Instead the standards describe a system that will help an organization to achieve its own objectives and targets. The assumption is that better environmental management will lead to better environmental performance (Tibor and Feldman 1996) and increased profitability (Dechant and Altman 1994).

An effective EMS can help a firm manage, measure, and improve the environmental aspects of its operations. It has the potential to lead to more efficient compliance with mandatory and voluntary environmental requirements. It may help companies affect a culture change as environmental management practices are incorporated into its overall business operations. According to Tibor and Feldman (1996) and Cascio (1994) the purpose of the EMS standard is to enable the company to:

- Establish an environmental policy appropriate to the organization.
- Identify the environmental aspects of the organization's products, services, and activities to determine both impact and significance.
- Identify priorities and establish objectives.
- Establish a program to implement these policies and objectives.
- Facilitate planning, control, monitoring, and changes to ensure policy is complied with and remains appropriate for the organization.
- Be ready to adapt to changes in the business environment.
- Identify the relevant legislative and regulatory requirements.

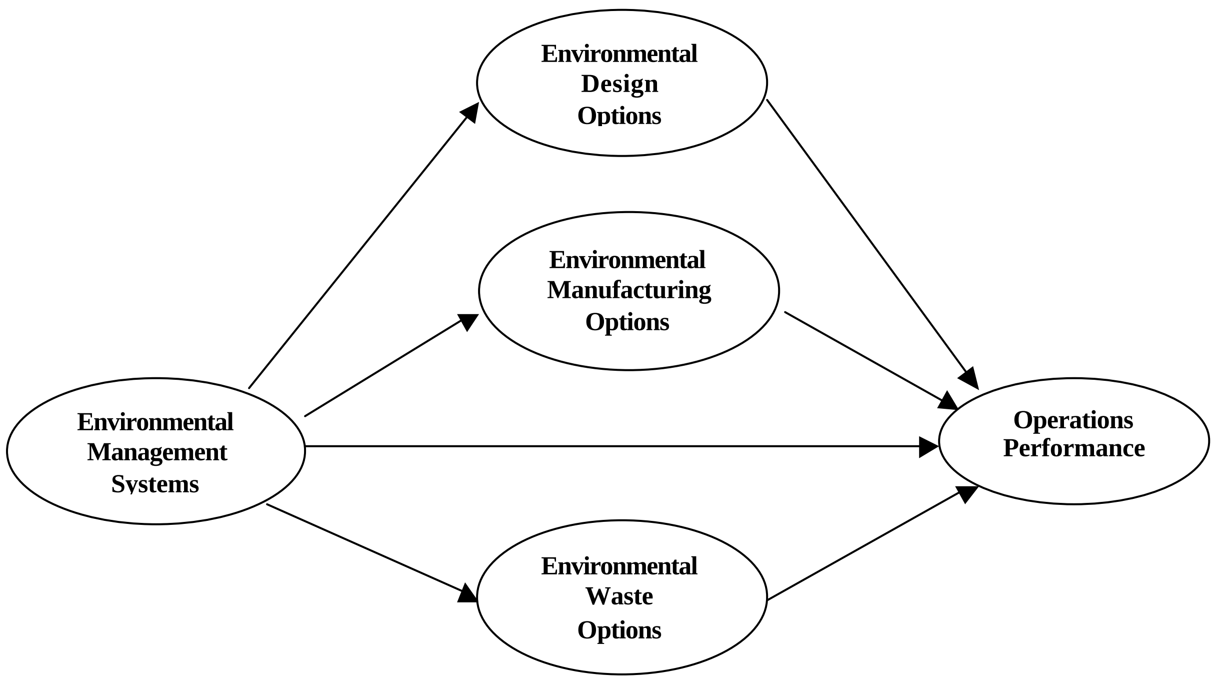
A challenge facing companies is that environmental data may reside in parallel information systems apart from corporate data (Fitzgerald 1994; Sroufe, Curkovic, Montabon, and Melnyk 2000). Environmental projects are ultimately a cross-functional undertaking, and affects all of the functional areas of a business enterprise (Kleiner 1991; Post 1991; Williams 1991). It is here in the manufacturing process, that firms set into place the actions that ultimately create the waste streams encountered in the transformation system. Operations Management determines what items will be produced, where, and in what quantities. These decisions, in turn, cause the consumption of resources and the creation of waste. One way of controlling and reducing environmental waste streams is to integrate systems and practices to achieve better environmental performance. Thus, the first hypothesis in this study involves the relationship of an EMS to the environmental management practices a firm engages. (See appendix 1 for a list of all constructs and measures used in this study)

Hypothesis 1: EMS development is positively related to the environmental practices a firm considers.

3. Environmental Management Practices

For the purpose of this study, three latent variables represent a range of environmental practices a firm can be involved in. These constructs are not all inclusive, but attempt to capture the importance of various options considered by a firm when facing environmental design, manufacturing, or waste reduction initiatives.

Figure 1. Conceptual Model



3.1 Design Practices

The NPD process embodies all of the steps necessary to take the product from concept to full production. This process has undergone extensive revision and rethinking (Hall 1993; Patterson 1993) due to increased market pressures to reduce the total cycle lead time (from concept to full production), reduce cost, enhance product flexibility and improve product quality (Cohen and Apte 1997). These pressures, are some of the same forces that impact developments such as TQM, JIT, and Time Based Competition (TBC) (Stalk and Hout 1990) and Mass Customization (Pine 1993).

One can envision the NPD (i.e. product/process design and delivery system) as consisting of seven linked stages (Meyer 1993). In all stages of the NPD process, environmental factors must be considered in addition to all other objectives and issues (Peattie 1992). Furthermore, one function or group no longer manages each activity in isolation. Rather, there is integration of multiple groups or stakeholders, both internally, with other functions, and externally with stakeholders, customers and suppliers. In the earlier stages of NPD, meeting the needs of stakeholders "such as regulators" is important. In the later stages of NPD, working with suppliers, customers, special interest groups and third party endorsement of products becomes important (Polonsky and Ottman 1998; Polonsky, Rosenberger, and Ottman 1998).

Much of the prior research attention has been focused on product/process design (Allenby 1993). This attention correctly recognizes the importance of product design to overall performance. After all, decisions made during this stage have a significant impact on environmental performance. For example, Fabrycky (1987) estimated that up to 85 percent of the life cycle costs are committed by the end of the preliminary design stages. In another study, Ulrich and Pearson (1993) found that at least 50 percent of the costs (for a class of mature products) are design determined and that up to 70 percent of costs are affected by manufacturing process decisions.

The use of green design is increasing (BSR 1998). This use of design to realize better environmental performance should not be surprising, since the design process is one of the major tasks for any firm. Design activities, in general, present opportunities for firms to find solutions to environmental issues (Lozada and Mintu-Wimstatt1995). These design activities shape the scope of the transformation process by determining the types of inputs required and outputs created. Inputs involve information about the substitution of lesser hazardous alternatives for previously hazardous materials. Through the use of an environmental design approach, products and processes are designed such that emissions and wastes are either minimized or completely removed (Tibor and Feldman 1996). Given the importance environmental design issues, these practices should have a strong and positive relationship with performance. For the purpose of this study, performance is operationalized as a respondent's perceptive measure of the impact of environmental practices on firm performance.

Hypothesis *2: Design practices are positively related to firm performance.*

3.2 Manufacturing Practices

Results from McKinsey and Company (1991) show production being perceived as the most critical phase of a product's life i.e., sourcing, production, use, and disposal. Since manufacturing practices are strongly cross-functional in nature, to be successful from both a corporate and marketing perspective, the product design and manufacturing activities must consider the perspectives of multiple parties and stakeholders (Polonsky and Ottman 1998; McDaniel and Rylander 1993). This cross-functional approach helps integrate information about the ability of the firm to remanufacture, or rebuild a product.

Leverage for a firm to focus on manufacturing practices comes from McKinsey and Company (1991) who found production as being a major part of a firm's ability to meet 50% waste reduction goals. Additional support is found in Klassen (2000) and the link between advanced manufacturing practices, pollution prevention, and operations.

Implicitly included in the before mentioned studies are the concepts such as remanufacturing and rebuilding products. Remanufacturing and rebuilding products is really an attempt to provide greater value to customers with fewer materials. Firms are continuously exploring ways to reduce the amount of material in their products. One way of reducing waste while simultaneously impacting environmental performance, pollution prevention, and quality (Klassen and Whybark 1999b), is through environmental manufacturing practices. Therefore, environmental manufacturing practices should have a positive impact on performance.

Hypothesis *3: Manufacturing practices are positively related to performance.*

3.3 Waste Practices

One of the main reasons for firms to reduce waste involves the control of costs (GEMI 1997). Royston (1980) also emphasizes control of costs and pollution abatement through waste detection, and selling residuals as raw materials. Additionally support for this approach to cost reduction and waste management is found in Hart and Gautam (1996). Hart and Gautam's research finds a link between emission reductions and firm performance. Based on the findings of previous research environmental waste practices are impacted by the EMS and in turn can impact firm performance (GEMI 1994).

Waste management practices can be as simple as segregating waste streams and recycling, or as complex as strategic alliances and relocation of the manufacturing facilities. Other waste management options explored in this study include creating a market for waste materials, or consuming internally (i.e., reusing) waste materials. These waste related practices involve innovations that lower the total cost of a product or improve its value allowing companies to use a range of inputs more productively and thus offsetting the costs of improving environmental impact as suggested by Porter and van der Linde (1995a).

In order for a firm to develop waste reduction practices, there needs to be an integrated system to make information available to the key people involved. A company's ability to accurately reflect the costs associated with current or proposed products and processes being the most critical information required in order for an environmental initiative to be given serious consideration (Sarkis and Rasheed 1995).

The presence of an EMS can facilitate better management of waste-related costs and, ultimately, more informed managers involved in decisions about waste management.

Hypothesis 6: Environmental waste practices are positively related to performance.

4. Impact of Environmental Practices on Performance

This section describes the potential benefits to performance that come about from different environmental management practices, programs and systems. These benefits and the theoretical linkages of the proposed conceptual model in Figure 1 are based on the resource-based view of the firm, the natural resource based-view of the firm, and corporate social performance.

The resource-based view of the firm posits that competitive advantage can be sustained if the capabilities creating the advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). These resources are considered valuable, rare, and in fact raise barriers to imitation, and entry (Barney 1991). An EMS can provide information used to aid decision making, enhance firm image, or if part of a certified standard, can facilitate entry into markets having restriction on entry. Borrowing from the resource based view of the firm, a unique resource such as an EMS can provide specialized information and enhance performance.

According to Starik and Rands (1995), organizations have environmentally oriented interactions with other levels and systems, internal and external to the firm. The multilevel interactions exist, whether planned and/or recognized. A complimentary theory to Starik and Rands thinking, is the natural-resource-based view of the firm. This theory is centered on the premise that business will be constrained by and dependent upon ecosystems (Hart 1995). The natural-resource-based view suggests that strategy and competitive advantage in the coming years will be rooted in capabilities that facilitate ecologically sustainable economic activity (Hart 1995; Jennings and Zandbergen 1995; Magretta 1997).

Benefits also include using an EMS as a means for companies with typically bad environmental practices to demonstrate a change in ways (Litskas 1999), or improved corporate social performance (Waddock and Graves 1997). This improved social responsibility can be seen as a product the firm has to offer to the key publics of the firm (Murry and Montanari 1996). It is hypothesized that the more integrated the EMS system, the more environmental practices a firm will be involved in, and the greater the positive impact on firm performance.

Hypothesis 5: An EMS is indirectly related to performance through the environmental practices the firm is involved in.

Hypothesis 6: An EMS is directly related to performance.

5. Research Methodology

The primary approach for data collection is a survey complemented by field interviews at selected plants. Multiple industries were chosen for implementation of the survey instrument to show what is happening within several industries rather than being limited to environmental business practices of isolated extreme cases such as those already highlighted in previous literature (Walley and Whitehead 1994; Clarke, Stavins, Greeno, and Bavaria et.al. 1994; Clarke, Cairncross, Walley, Whitehead, et. al. 1994; Porter and Van Der Linde 1995a).

The research questionnaire was developed and pre-tested by 15 respondents in a three-round process over a period of two months. This group represented a variety of positions and functions within their firms in a variety of industries. The 16 page survey with 250 items was developed to establish measures for new environmental concepts. The full survey and complete sample information is available in (Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe, and Montabon 2000).

Three professional associations provided mailing lists of 5,000 names each. To date, this is the largest implementation of an environmental survey involving EMS and ISO 14000. Of the 15,000 questionnaires mailed, 1,510 questionnaires were returned constituting a response rate of just over 10%. The level of analysis for this study is manufacturing firms at the plant level. While it is possible to pursue scale development and verification of the validity of the measurement model using the 1510 responses, it is better to use complete data from each respondent. After eliminating non-manufacturing industries a subset of the full data set included 1331 respondents. After listwise deletion the sample size was 1118. The majority of respondents were managers, the mean sales for the resulting sample was $962.016 Million, with a standard deviation of 80 Million. The mean number of employees was 4,253 with a standard deviation of 30,002.

To detect nonresponse bias, variables important to the conceptual model were tested to see to try and find differences between early respondents and late respondents. A random sample of 10% was taken from each of the early and late respondent groups. A comparison of the groups was performed using a random selection of the variables in each of the constructs posited in the conceptual model. The t-test comparing the sample means for each of the variables across groups revealed no statistical significance. These findings suggest non-response bias is not a problem in this study (Armstrong and Overton 1977)

5.1 Field Studies

Field-based data collection methods were used to ensure that important variables were captured during the interview process. These methods also helped develop an understanding of why these variables might be important Eisenhardt, (1989). A small detailed sample fit the needs of the research and complimented the large-scale survey. The method followed was similar to the grounded theory development methodology suggested by Glasser and Strauss (1967). In addition, suggestions made by Eisenhardt (1989) regarding case studies, Miles and Huberman (1994) regarding qualitative data analysis, and Yin (1994) were incorporated.

In instances where there does not exist a well developed set of theories regarding a particular branch of knowledge, Eisenhardt (1989) and McCutcheon and Meridith (1993) suggest that theory-building can best be done through case study research. Comparative literature reviews of research on environmental management systems confirm definitional ambiguity and early theoretical development (Klassen and Whybark 1999b; Porter and van der Linde 1995b). In this stage of theory building, a key objective is to characterize the different types of firms involved in EMS development.

5.2 The Field Study Sample

Cook and Campbell (1979) suggested that random samples of the same population be used in theory testing research. However, the sample selected for qualitative research, such as in this study, should be purposeful and based on theoretical underpinnings (Eisenhardt 1989; Miles and Huberman 1994).

The role of the field research was to enhance quantitative findings obtained from the large-scale survey through adding a description of systems and metrics behind the EMS development decisions. Using qualitative case studies (in addition to a quantitative survey) serves the purposes of a *data triangulation* (through adding a different data source) and a *methodological triangulation* (through relying on both qualitative and quantitative methods) (Creswell 1994). The combination of qualitative and quantitative methods in a mixed methodology is an often-overlooked approach in the field of operations management. This study attempts to overcome the deficiencies of any one approach through by using a triangulated approach.

Eight companies were selected representing different stages of the EMS certification process. Table 1 summarizes the respondents, status of EMS development, and the types of the firms visited. The field studies were part of a larger research project and only 2 of the research protocol questions are used for this study (Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe, and Montabon 2000):

1. What type of EMS is in place?
2. How is environmental performance measured?

The objective was to construct a sample of firms that would be diverse enough to capture the EMS attributes available across firms that may be overlooked in a single industry or product sample and to confirm findings from the large scale survey. An examples of data from a single site visit is in Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe, and Montabon (2000).

Table 1. Categorization of Field Study Firms by EMS Certification Status

Firms Visited	Respondent	Status of EMS Development
Firm A: Automotive Casting Facility Firm B: Metal Fastener Manufacturer	Firm A: Environmental Engineer (7yrs) Firm B: Operations Manager (4 years)	Not Being Considered
Firm C: Office Furniture Manufacturer Firm D: Pharmaceutical Company	Firm C: Corporate Environmental Manager (6years) Firm D: Manager “Leader” Environment and Safety (16 yrs)	Assessing Suitability
Firm E: Automotive Glass Assembly	Firm E: Manager of Technical Services “Quality and Environmental Manager” (13 years)	Planning to Implement
Firm F: Break Systems Manufacturer Firm G: Automotive Glass	Firm F: Manager, Health, Safety, & Environmental Quality (1 year in current position) Firm G: Corporate Manager of Safety and Environmental Strategies (26 years) and the Operations Management Manager for the nearest facility (2 years)	Implementing (at the time of data collection)
Firm H: Engine Parts Manufacturer	Firm H: Manager of Environmental Systems (5yrs, 25 environmental)	Successfully Implemented

The reasons for using a single method or paradigm “qualitative, or quantitative” according to Creswell (1994), are pragmatic, such as the extensive time required to use both paradigms adequately, the expertise needed by the researcher, the desire to limit the scope of the study. The multimethod, or “triangulation” approach is based on the assumption that any bias inherent in particular data sources, investigators, and methods would be neutralized when used in conjunction with other data sources, investigators and methods (Jick 1979).

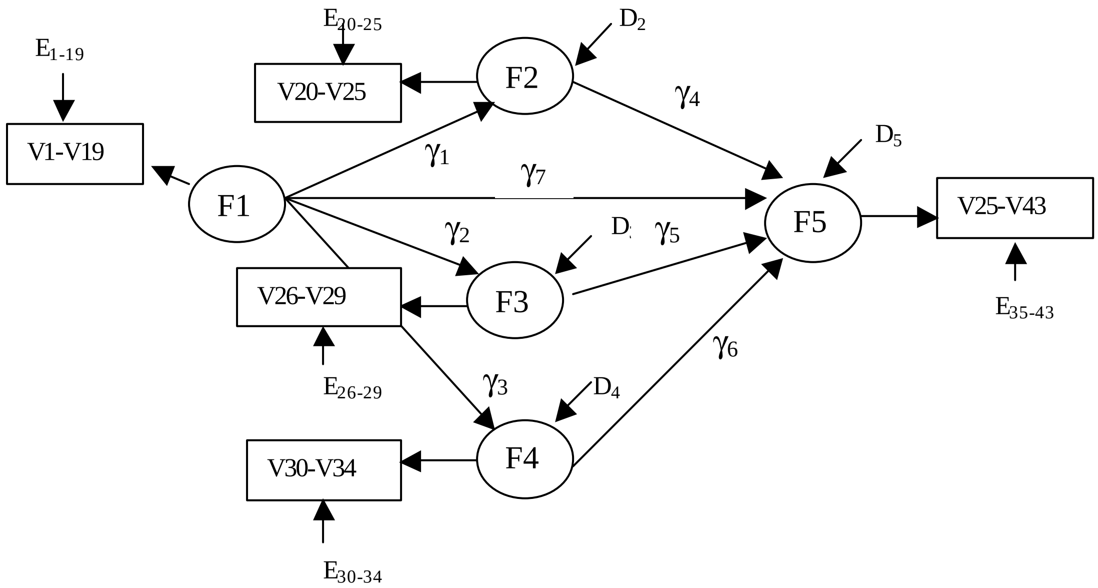
6. Data Analysis

SEM is similar to path analysis in that it provides parameter estimates of the direct and indirect links between observed variables. An important distinction is that SEM explains covariation in the data. SEM requires formal specification of the model to be tested and requires the researcher to think and hypothesize relationships a priori. SEM is similar to regression techniques in that there is a quantification of relationships between dependent and independent variables. Using SEM is a more comprehensive and flexible approach to research design and data analysis than a single statistical model or approach. One of the unique features of SEM is the ability to provide parameter estimates for relationships among unobserved variables. A SEM implicitly asserts a covariance structure whose concordance with the observed covariance based on the data can be tested (Jöreskog and Sörbom 1989).

For the analysis of the survey data in this study, EQS (Bentler 1989) is used. This software is generally identical to LISREL (Jöreskog and Sörbom 1989), but uses simpler terminology and notation (Brown 1986). The goodness-of-fit test is carried out using chi-square and other tests, which are available in EQS. To date, the most widely used fitting function is for structural equation modeling is the Maximum Likelihood (ML) function (Bollen 1989). Due to nonormality indicators, specifically a high positive Mardia’s coefficient, Elliptical Reweighted Least Squares (ERLS) was used for estimation of the data in this study, (Sharma, Durvasula and Dillon 1989).

Many researchers (Kenny 1979; Williams and Hazer 1986; Gerbing and Anderson 1988) propose a two-stage process of SEM in which the measurement model is first estimated, much like confirmatory factor analysis, and then the measurement model is fixed in the second stage when the structural model (see Figure 2). is estimated. The following sections of this paper discuss the results of the structural equation modeling two-stage process.

Figure 2. Structural Equation Model



Legend:
F1: Environmental Management System
F2: Environmental Design Practices
F3: Environmental Manufacturing Practices
F4: Environmental Waste Practices
F5: Perceived Impact of Environmental Practices on Firm Performance
γ_1 to γ_7: Estimated Path Coefficients
E_1 to E_{27}: Error terms in measurement model
D_1 to D_5: Error terms in the structural model

7. Results

The measurement properties were first assessed by testing a hypothesized measurement model using confirmatory factor analysis. While environmental research in business is still new, a strong *a priori* basis for the proposed model warranted the use of confirmatory factor analysis rather than an exploratory factor analytic approach. A confirmatory factor analysis is a more rigorous method for assessing unidimensionality when compared to Cronbach's alpha, exploratory factor analysis, and item total correlations (Gerbing and Anderson 1988). The use of reliability measures such as Cronbach's alpha does not ensure unidimensionality but instead assumes it exists (Cronbach 1951). The purpose of the CFA is to ensure unidimensionality of the multiple-item constructs and to eliminate unreliable measures.

While the most widely used statistic for assessing overall fit is the chi-square statistic, the use of multiple fit criteria such Normed (NFI) and Nonnormed Fit Indices (NNFI) (Bentler and Bonett 1980), and the Comparative Fit Index (CFI) (Bentler 1990), is an acceptable approach to assessing fit (Jick 1979). Each fit statistic provides a measure of complete covariation in the data, with a value greater 0.95 indicating an acceptable fit to the data (Bentler 1989).

7.1 Testing the Hypothesized Measurement Model

Initial testing of the hypothesized model yielded relatively high fit indices (i.e., in the low 0.90 range) and a relatively high chi-square to degrees of freedom ratio. When the 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 fit 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. The standardized solution of the measurement model with factor loadings and R-squared are given in Table 2.

Table 2. Standardized Solution

STANDARDIZED SOLUTION:	R-SQUARED
EMSDOC =V1 = .855 F1 + .519 E1	.731
EMSFORML=V2 = .844*F1 + .537 E2	.712
EMSDEPT =V3 = .785*F1 + .620 E3	.616
EMSCIRC =V4 = .822*F1 + .570 E4	.676
EMSRPT =V5 = .796*F1 + .606 E5	.633
EMSEPERF=V6 = .916*F1 + .402 E6	.839
EMSVIS =V7 = .849*F1 + .528 E7	.721
EMSEINF =V8 = .846*F1 + .534 E8	.715
EMSSUMM =V9 = .908*F1 + .418 E9	.825
EMSTRAIN=V10 = .844*F1 + .537 E10	.712
EMSGOALS=V11 = .917*F1 + .398 E11	.841
EMSPOS =V12 = .838*F1 + .546 E12	.702
EMSINEFF=V13 = .847*F1 + .532 E13	.717
EMSDATA =V14 = .855*F1 + .519 E14	.731
EMSOUTEF=V15 = .811*F1 + .585 E15	.657
EMSDIST =V16 = .861*F1 + .509 E16	.741
EMSCAUSE=V17 = .716*F1 + .699 E17	.512
EMSACHV =V18 = .818*F1 + .576 E18	.668
EMSREASN=V19 = .688*F1 + .726 E19	.473
OPTSUB =V23 = .831 F2 + .556 E23	.691
OPTREDUC=V24 = .873*F2 + .487 E2	.763
OPTPROC =V25 = .822*F2 + .570 E25	.675
OPTPROD =V26 = .783*F2 + .622 E26	.613
OPTDIS =V27 = .756*F2 + .655 E27	.571
OPTRECYC=V28 = .712*F2 + .702 E28	.507
OPTREMAN=V35 = .779 F3 + .627E35	.607
OPTREBLD=V36 = .808*F3 + .589 E36	.653
OPTPROLN=V37 = .626*F3 + .780 E37	.392
OPTCONSM=V38 = .632*F3 + .775 E38	.400
OPTSEG =V29 = .667 F4 + .745 E29	.445
OPTCREAT=V30 = .702*F4 + .712 E30	.492
OPTRELOC=V31 = .561*F4 + .828 E31	.315
OPTSPRED=V33 = .573*F4 + .819 E33	.329
OPTREPCK=V34 = .624*F4 + .781 E34	.389
ACTQUAL =V39 = .851 F5 + .525 E39	.724
ACTPOS =V41 = .852*F5 + .524 E41	.725
ACTPRODS=V42 = .838*F5 + .546 E42	.701
ACTCOST =V43 = .779*F5 + .627 E43	.607
ACTWEQIP=V44 = .819*F5 + .574 E44	.671
ACTINTER=V45 = .765*F5 + .644 E45	.586
ACTWPROD=V47 = .793*F5 + .609E47	.629
ACTBENE =V48 = .764*F5 + .645 E48	.584
ACTIS =V49 = .686*F5 + .727 E49	.471

Based on the information in the literature review a hypothesized list of constructs and measures was developed (Appendix 1). The final measurement model resulting from the initial hypothesized CFA model has few changes. Appendix 1 lists the constructs and measures used for the final measurement model. After dropping five of the original 48 measures in the CFA model, the final measurement model was run using both ML and ERLS estimation. The ERLS results from the measurement model are displayed in Table 3.

Table 3. Goodness-of-Fit Summary for the Measurement Model

Degrees of freedom (df)	850
Sample Size	1118
Chi-squared value	6171
Chi-squared/df ratio	7.26
p-value	< 0.001
Bentler-Bonnett Normed Fit Index (NFI)	.963
Bentler-Bonnett Non-Normed Fit Index (NNFI)	.963
Comparative Fit Index	.968
Standardized RMR	.048

The measurement model yielded a χ^2 = 6171.096, with 850 degrees of freedom and fit indices NFI, NNFI, and CFI all above .96. The goodness of fit indices indicated a well-fitting model. If either the χ^2 goodness-of-fit test or adjunct fit indexes indicate acceptable overall fit of a specified model, then the focus moves to the full model.

7.2 The Full Structural Equation Model

The full structural equation model in Figure 2 subsumes both the measurement model and the structural model. In the full SEM, latent variables (F1 through F5) are connected by one-way causal arrows, where the directionality reflects the hypotheses encompassing the causal structure of the model (as indicated by λ_1 through λ_7).

The structural component of the model in Figure 2 represents the hypotheses that an EMS (F1) indirectly influences the different practices a firm may engage in, such as design, manufacturing, and waste practices (F2, F3, and F4). An EMS is also posited to directly influence the perceived impact of environmental processes on performance (F5).

The full SEM was estimated using both ML and ERLS. Estimation results for the full model are given in Tables 3 and 4. ERLS estimation of the full model resulted in a χ^2 = 6700, 853 degrees of freedom, and fit indices for NFI, NNFI, and CFI all above .96. Based on the goodness-of-fit statistics there is a high degree of fit in the posited model. The results of the full model and significant positive path coefficients for λ_1 through λ_7 support hypotheses 1 through 6.

Table 3. Goodness-of-Fit Summary for the Full Structural Equations Model

Degrees of freedom (df)	853
Sample Size	1118
Chi-squared value	6700
Chi-squared/df ratio	7.85
p-value	< 0.001
Bentler-Bonnett Normed Fit Index (NFI)	.960
Bentler-Bonnett Non-Normed Fit Index (NNFI)	.963
Comparitive Fit Index	.965
Standardized RMR	.076

The measurement model has good fit with the data relative to the early stages of construct development in this field. The data also fit the full structural equation model well with all fit indices over .96 with an error term of 0.07. The CFI of the full model exceed the levels of 0.95 suggested by Bentler (1989) for confirmed models.

Table 4. Measurement Equations with Standardized Errors and Test Statistics

Regression from	Coefficient to	Parameter Estimate	Standard Error	t-value
F1	F2	.628	.032	19.687*
F1	F3	.460	.034	13.471*
F1	F4	.516	.033	15.433*
F1	F5	.230	.041	5.601*
F2	F5	.203	.034	5.992*
F3	F5	.105	.030	3.494*
F4	F5	.230	.048	4.799*
*p < 0.05				

8. Defining the New EMS Construct and Relationships

With definitional ambiguity leaving practitioners with few frameworks and insights, researchers need to understand how to measure and operationalize the EMS construct. Very little empirical research exists as to what the defining attributes of an EMS really are, or how EMSs impact firms. A new definition of an EMS can go a long way toward a better understanding of what does and does not constitute an EMS, what activities plants should be engaged in, and where scarce resources should be allocated.

EMS construct development is based on the literature review, experiences of the researcher, hypotheses and subsequent results of the data analysis. The results of the measurement model, much the same as a confirmatory factor analysis indicate construct validity and reliability for the nineteen manifest variables comprising the latent EMS construct. Additional analysis using a standardized coefficient alpha for the EMS construct and 19 measures results in a 0.977 for this summated scale. A new definition of an EMS is based upon the literature review, manifest variables from the EMS construct, and confirming field studies. Thus an EMS is:

> The formal system and database which integrates procedures and processes for the training of personnel, monitoring, summarizing, and reporting of specialized environmental performance information to internal and external stakeholders of the firm. The documentation of this "environmental" information is primarily internally focused on design, pollution control and waste minimization, training, reporting to top management, and the setting of goals. The use of this information for external stakeholders is primarily found in annual reports, focuses on the outputs of the firm, and is used to enhance firm image.

Next, I discuss the field studies and hypotheses involving the relationship of an EMS to environmental practices and performance.

Hypothesis 1*:* EMS development is positively related with the environmental practices a plant participates in. The results of the measurement model and summated scale demonstrate construct validity and reliability, while the full SEM links this new EMS construct to environmental practices and performance. The results show γ_1 equal to .628, p-value < 0.05 for the relationship to design; $\gamma_2 =$ .406, p-value < 0.05 for the relationship to manufacturing practices; and $\gamma_3 =$ .516, p-value < 0.05 for the relationship to waste practices. Thus, EMS does positively impact the environmental practices present in the hypothesized model. The EMS construct involved variables such as the extent of a firm's formal EMS, top management support for the system, the documentation, tracking and reporting of environmental information, use of performance goals, training, internal and external perceptions of the system. The EMS construct has strong relationships to environmental design, manufacturing and waste practices as posited. The resource-based view discusses capabilities creating a competitive advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). It is here we can see the formal EMS, documentation, goals, and training providing specialized environmental information at the plant level which allows for the use of the different environmental practices.

Additional information from the field studies shows that many of the firms involved in the certification of an EMS i.e., firms E, F, G, and H, had linked these systems to design and waste metrics. Here we see EMS and environmental design and waste practices measured, tracked and managed in firms planning on implementing, currently implementing, or who have successfully implemented a certified EMS. Information from the field studies also supports the literature suggesting firms having key executives that aggressively pursue environmental growth opportunities will be more inclined to invest in an EMS.

Hypothesis 2: Design practices are positively related to performance. $\gamma 4$ = .203, p-value < 0.05. This relationship is relatively small, but significant. Design practices include the use of substitution, reduction of materials contributing to environmental problems, the use of product and process redesign to eliminate potential environmental problems, redesigning to aid in disassembly, and the increased use of recycled components.

The results show that design practices are closely interrelated and greatly influence each other while simultaneously impacting performance. These design activities, in general, present opportunities for firms to find solutions to environmental issues (Lozada and Mintu-Wimstatt 1995; Sroufe, Curkovic, Montabon, and Melnyk 2000). These activities, shape the scope of the transformation process by determining the types of inputs required and outputs created. Inputs can involve information about the substitution of less hazardous alternatives for previously hazardous materials. Design practices basically involve the incorporation of environmental considerations into product and process engineering design procedures (Allenby and Fullerton 1992). Results support the goals of environmentally responsible manufacturing to be more readily achieved when environmental issues are identified and resolved during early stages of product and process design, when changes can be made to reduce or eliminate environmental waste (Allenby 1993). Additional support of the findings of this research are found in Design for Environment literature which argues that the greatest opportunities for waste minimization exist during the design process (Allenby and Fullerton 1992; Allenby 1993; Sroufe, Curkovic, Montabon, and Melnyk 2000).

Hypothesis 3: Manufacturing practices are positively related to performance. γ_5 = .105, p-value > 0.05. This relationship, defined very narrowly to include remanufacturing, rebuilding and the consumption of waste internally, is not as strong as posited. Manufacturing practices, as operationalized, include remanufacturing, where none of the parts are reduced to raw materials, rebuilding where some of the parts or components are recovered while others are replaced, and the consumption of materials internally i.e., the consumption of waste materials to generate electricity.

Based on the results of this study, there is a need for further examination of the relationships posited and demonstrated. There is previous evidence that firms are finding performance improvements from investments in manufacturing technology (Klassen 2000). Since manufacturing practices are strongly cross-functional, these activities should impact multiple stakeholder (Polonsky and Ottman 1998; McDaniel and Rylander 1993).

In the dynamic environment captured by the SEM, environmental manufacturing practices, may be overlooked in the presence of strong design and waste practices. The results support the idea that these narrowly defined environmental manufacturing practices only have minimal impact the strategic dimensions of the plant and their impact may be more tactical in nature. Further examination is warranted.

The SEM results are also echoed by the field studies. The field studies show that for all of the firms involved in EMS development, or certification, i.e., E, F, G, H, and firm D, these firms focused on some design, little manufacturing, and primarily waste, or output practices and performance measures. Given this, the firms in this study were not measuring, monitoring, or managing environmental manufacturing practices with as much attention as design and waste practices. This is not much of a surprise given increased regulations and special interest groups turning attention to outputs and waste reduction, firms may focus more on output wastes from a corporate social performance perspective (Wood 1991; Pava and Krausz 1996).

Hypothesis 4: Waste practices are positively related to performance. $\gamma_6 = .230$, p-value < 0.05. Thus, an EMS impacts waste management practices directly and performance indirectly. Waste practices include: use of waste segregation; selling waste as an input to another product; the use of relocating a process or plant to take advantage of more favorable environmental regulations; the use of alliances with suppliers or customers to address environmental problems; an increased shifting of responsibilities to third parties better able to deal with the issues; and an increased use of returnable packaging to reduce solid waste. Much the same as the results from hypothesis 2 and 3, and the field studies, there seems to be ample evidence of firms using environmental waste practices and these waste practices do impact performance.

The results support the idea that initiatives such as segregation, selling of waste and alliances have a positive impact on the firm. We would expect these impact to be greater than those of traditional, inefficient ways of dealing with environmental issues in a reactive, ad-hoc, end-of-pipe manner (Global Environmental Management Initiative 1996). Thus, waste management practices can be as simple as segregating waste streams and recycling, or as complex as strategic alliances and relocation of the manufacturing facilities.

Hypothesis 5: Performance is indirectly related to EMS through the environmental practices a firm is involved in. As evident from the SEM results and hypothesis 1 through 4, hypothesis 5 is supported. Tibor and Feldman (1996) support the overall results for hypothesis 5 by claiming that environmental management will lead indirectly to better environmental performance. The premise is that improved systems associated with EMSs, such as those used in design, manufacturing, and waste practices of plants, will make achievement of performance goals more likely.

Additionally, the resource-based view of the firm posits that competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by a firm’s competitor (Rumelt 1984). EMS may be such a unique resource to a firm that the specialized information supplied by the system allows for better decisions making, that otherwise would not be possible. Manufacturing plants should be able to utilize a formal EMSs, documentation, reporting, environmental performance measurement, and training to facilitate more effective and efficient operations performance.

Finally, as discussed in hypotheses 1 through 4, the field studies support the overall findings that EMSs are indirectly related to enhanced operations performance. Interviews at firms F, and D show that plants are realizing there are many hidden environmental costs and that these costs can now be tracked, and managed to reduce costs while also giving more leverage to the environmental practices of the firm.

Hypothesis 6: An EMS is directly related to performance, $\gamma_7 = .230$, p-value < 0.05. There is a significant and positive relationship between an EMS and performance. Based on the measures used for each construct, there is a direct relationship between a plants EMS, top management support for the system, documentation, tracking and reporting of environmental information, use of performance goals, training, internal and external perceptions of the system, and performance measures. This relationship demonstrates that an integrated EMS will positively impact operations performance measures such as quality, decrease costs, improve the firm’s position in the marketplace, bring about better products, help equipment selection decisions, reduces waste in production, improve chances of selling products in international markets, and has benefits that outweigh the costs.

Results of the research indicates an EMS is related to more than just environmental performance in that these types of systems help improve products and plant image, reduced costs, and much the same as investments in technology and findings of Klassen (2000), also improve quality. The field studies show that firm F was able to prove the environmental department within the plant is a “benefit and not a cost” to the organization. Additionally, the information from the respondents in the field studies at firms C, D, F and H all suggest that the benefits of an EMS outweigh the costs.

9. Discussion and Conclusions

The research is aimed at satisfying academic and practitioner interests in environmental business practices. From an academic perspective, the goal was to develop and assess a rationally consistent theory of EMS. Operationalizing the EMS construct bridges gaps in the literature while simultaneously building theory. The multimethod approach of qualitative and quantitative approaches to the data collection and analysis lends itself well to the development of valid and reliable scales for the latent variable of an EMS. Theory building is supported through the explanatory and predictive powers of the model.

The results should be of interest to managers faced with decisions regarding EMSs and environmental practices. In situations where environmental projects may be thought of as a "cost of doing business," the results of the research provide evidence of benefits that exceed the costs, and help practitioners understand the attributes of a EMS. The results of the analysis, demonstrate the link between environmental systems environmental practices and performance. The research also demonstrates the link to operations performance measures such as cost, and quality.

Klassen and Whybark (1999b) discuss an environmental technology portfolio as an implicit or explicit strategy resulting in a pattern of investment in environmental technology which improves environmental performance. The results of this study support EMSs being explicit and an overlooked part of the environmental technology portfolio. Based on the results of this study, an EMS has many impacts on environmental management and operations. There appears to be a need to expand the environmental technology portfolio to include a more rigorous definition and measurement of systems. Additionally, there is a need to better understand how firms integrate EMSs into existing operatoins processes.

For an EMS to be effective, it should be involved in the monitoring, tracking, summarizing and reporting of environmental information to internal and external stakeholder. There is also a need for integrating cross-functional activities to include environmental training of personnel. Finally, there is the need for formal procedures and the availability of these procedures and information to people in new product design, process design, and packaging. A firm's commitment to an EMS will be a determining factor in the success of the system and the extent of the benefits derived from environmental efforts.

References

ALLENBY, B.R. (1993). *Industrial Ecology*. New York, NY: Prentice-Hall.

ALLENBY, B. R., AND FULLERTON, A. (1992), "Design for Environment—A New Strategy for Environmental Management." *Pollution Prevention Review*, winter, 51-61.

ARMSTRONG J.S. AND T.S. OVERTON (1977), 'Estimating Nonresponse Bias in Mail Surveys,' Journal of Marketing Research 14, 3, 396-402.

ARTHUR D. LITTLE (1989), *State of the Art Environment, Health and Safety Management Programs: How Do You Compare?* Arthur D. Little Inc. Center for Environmental Assurance, Cambridge, MA.

BARNEY, J. (1991), Firm Resources and Sustained Competitive Advantage. *Journal of Management*, 17, 99-120.

BENTLER, P.M. (1989), *EQS: Structural Equations Program Manual, Version 3.0*, BMDP, Statistical Software Inc., Los Angeles, CA.

BENTLER, P.M., (1990), "Comparative Fit Indexes in Structural Models." *Psychological Bulletin*, 107, 238-246.

BENTLER P.M., AND BONETT, D.G., (1980), "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures." *Psychological Bulletin*, 88, 588-606.

BOLLEN, K.A., (1989), *Structural Equations with Latent Variables*. New York, John Wiley.

BROWN, R. L. (1986), "A comparison of the LISREL and EQS programs for obtaining parameter estimates in confirmatory factor analysis studies." *Behavior Research Methods, Instruments and Computers*, 18 4, 382-388.

BRYNE, B.M., (1994), *Structural Equations Modeling with EQS and EQS/Windows*. Sage Publications, Thousand Oaks California.

BUSINESS FOR SOCIAL RESPONSIBILITY (BSR) Education Fund, (1998), *Moving Toward Sustainability: A View of Leadership Company Practices and Stakeholder Expectations*, Business and the Environment Program, San Francisco, CA.

CASCIO, J. (1994), "International Environmental Management Standards." *ASTM Standardization News*, April, 44-48.

CLARK, R.A., STAVINS, R.N., GREENO, J.L., BAVARIA, J.L., ET. AL. (1994), " The Challenge of Going Green," *Harvard Business Review*, July-August, 72, (4), 37-49.

CLARK, R.A., CAIRNCROSS, F., WALLEY, N., WHITEHEAD, B., ET. AL.(1994), "The Challenge of Going Green—Comment/reply," *Harvard Business Review*, July-August, 72, 4, 37.

COHEN, M.. AND APTE, U. (1997), *Manufacturing Automation*, Irwin. Burr Ridge, IL. Chpt. 2.

CORBETT, C.J., AND KIRSCH, D.A. (2001), "International Diffusion of ISO 14000 Certification," *Production and Operations Management*, 1, 3, 327-342.

COLLINS, D.J., AND MONTGOMERY, C.A., (1995), "Competing on Resources: Strategy for the 1990s." *Harvard Business Review*, July-August, 57-71.

COOK, T. AND CAMPBELL, D. (1979), *Quaisi-Experimentation - Design and Analysis Issues for Field Settings*. Houghton-Mifflin, Boston.

CRESWELL, J.W. (1994), *Research Design: Qualitative and Quantitative Approaches*. Sage Publications.

CRONBACH, L.J., (1951), " Coefficient Alpha and the Internal Structure of Tests." *Psychometrica*, 16, 297-334.
DANIELS, S. E. (2000), "Management System Standards Poised for Momentum Boost," *Quality Progress*, 33, 3, 31-38.
DECANT, K., AND ALTMAN, B. (1994), Environmental Leadership: From Compliance to Competitive Advantage. *Academy of Management Executives*, 8, 3, 7-20.
EISENHARDT, K. M. (1989), "Building Theories from Case Study Research." *Academy of Management Review*, 14, 4, 532-550.
EPSTEIN, M.J., (1996), Measuring Corporate Environmental Performance: Best Practices for Costing and Managing an Effective Environmental Strategy. Montvale, NJ: The IMA Foundation for Applied Research, Inc.
FABRYCKY, W. (1987), "Designing for the life cycle", *Mechanical Engineering*, January.
FELDMAN, S. J., SOYKA, P. A. AND AMEER, P. (1997), "Does Improving a Firms Environmental Management System and Environmental Performance Result in a Higher Stock Price?" Environmental Group Study, January, ICF Kaiser International, Inc.
FITZGERALD, C. (1994), "Environmental Management Information Systems: New Tools for Measuring Performance." *Total Quality Environmental Management*, Winter, 22-23.
FORD MOTOR COMPANY (1999), "Ford Is Dedicated to Protecting the Environment" Information packet on Ford and the Environment. Ford Motor Company, Detroit Michigan.
GARVIN, D.A. (1987), "Competing on the Eight Dimensions of Quality," *Harvard Business Review*, November - December, 101-109.
GLASER, B. & STRAUSS, A. (1967), *The discovery of grounded theory: Strategies for Qualitative Research*, Aldine, Chicago.
GLOBAL ENVIRONMENTAL MANAGEMENT INITIATIVE (GEMI) (1994), *Environmental Self-Assessment Program* (Third Ed.), Washington, D.C.: GEMI, November.
GLOBAL ENVIRONMENTAL MANAGEMENT INITIATIVE (GEMI) (1996), *ISO 14000 Environmental Management System Self-Assessment Checklist*, GEMI: Washington, D.C., March.
GLOBAL ENVIRONMENTAL MANAGEMENT INITIATIVE (GEMI) (1997), *ISO 14000 Measuring Environmental Performance*, GEMI: Washington, D.C., March.
GERBING, D.W., AND ANDERSON, J.C. (1988), "An Updated Paradigm for Scale Development Incorporating Unidimensionality and Its Assessment." *Journal of Marketing Research*, 25, 186-192.
GIFFI, C., A.V. ROTH, AND G.M. SEAL (1990), *Competing in World-Class Manufacturing: America's 21st Century Challenge*, Richard D. Irwin, Homewood, IL.
GREENWALD, J. (1997), "Partnerships Seek to Link Profits, Pollution Prevention." *Business Insurance*, 31, 23, 22-23.
HALL, R. (1993). *The Soul of the Enterprise*. Harper Business, New York, NY.
HART, S. L. (1995). A natural Resource Based View of the Firm. *Academy of Management Review*, 20, 986-1014.
HART,S.L., AND GAUTAM A. (1996), 'Does it Pay to be Green? An Empirical Examination of the Relationship Between Emission Reduction and Firm Performance'. Business Strategy and The Environment, 5, 30-37.
HAYES, R., AND S. WHEELWRIGHT (1984), *Restoring Our Competitive Edge: Competing Through Manufacturing*. New York: John Wiley and Sons.
HUNT, C.B., AND E.R. AUSTER (1990), "Proactive Environmental Management: Avoiding the Toxic Trap," *Sloan Management Review*, 31, 2, 7-19.
INTERNATIONAL ORGANIZATION OF STANDARDS (ISO) 14001: Environmental Management Standards, Released Fall. 1996.
JENNINGS, P. D., & ZANDBERGEN, P. A. (1995), Ecologically Sustainable Organizations: An Institutional Approach. *Academy of Management Review*, 20, 1015 - 1052.
JICK, T. D. (1979), "Mixing Qualitative and Quantitative Methods: Triangulation in Action," *Administrative Sciences Quarterly*, 24, 602- 611.
JÖRESKOG, K. G., AND SÖRBOM,, D. (1989), *LISREL VII: A Guide to Programming and Applications*. Chicago IL: SPSS Inc.
KENNY, D.A., (1979), *Correlations and Causation*. New York, Wiley.
KLASSED, R.D., (2000), 'Exploring the Linkage Between Investment in Manufacturing and Environmental Technologies." *International Journal of Operations and Production Management*, 20, 2, 127-147.
KLASSEN, R. D., AND WHYBARK, D.C. (1999a), "Environmental Management in Operations: The Selection of Environmental Technologies." *Decision Sciences*, 30, 3, 601-631.
KLASSEN, R. D., AND WHYBARK, D.C. (1999b), "The Impact of Environmental Technologies on Manufacturing Performance." *Academy of Management Journal*, 42, 6, 599-615.
KLEINER, A. (1991), "What Does It Mean to Be Green?" *Harvard Business Review*, 69, 4 , 38-47.
KRUT, R. AND DRUMMOND, C. (1997), Global Environmental Management: Candid Views of Fortune 500 Companies, US-Asia Environmental Partnership with the US Agency for International Development, October.
LITSKAS, M. (1999), "U.S. Perspective Varies on ISO 14000," *Quality*, Vol. 36, No. 12, December, 28-33.
LOZADA, H. AND MINTU-WIMSATT, A. (1995), "Green based innovation: sustainable development in production management", In *Advances in Environmental Marketing: New Developments in Practice, Theory and Research*. (Eds) Polonsky, M. J. and Mintu-Wimstatt, Hawworth Press, New York, 179 - 196.

MAGRETTA, J. (1997), Growth Through Global Sustainability, *Harvard Business Review*, January-February, 79-88.
MAKOWER, J. (1994), *The E-Factor: The Bottom-Line Approach to Environmentally Responsible Business.* New York: Times Books.
MARGUGLIO, B. W. (1991), *Environmental Management Systems,* Marcel Dekker, New York.
MCCUTCHEON, D. AND MERIDITH, J. (1993), "Conducting case study research in operations management", *Journal of Operations Management*. 11, 3, 239-256.
MCDANIEL, S. AND RYLANDER, D. (1993), "Strategic green marketing", *Journal of Consumer Marketing*, 10, 3, 4-10.
MCKINSEY AND COMPANY (1991), The Corporate Response to the Environmental Challenge, McKinsey and Company, Amstel 344, 1017 AS Amsterdam, The Netherlands, August.
MELNYK, S., R. CALANTONE, R. HANDFIELD, L. TUMMALA, G. VASTAG, T. HINDS, R. SROUFE, F. MONTABON, AND S. CURKOVIC (1999), *ISO 14000 Assessing Its Impact on Corporate Effectiveness and Efficiency,* Focus Study: Center for Advance Purchasing Studies.
MELNYK, S. A., SROUFE, R., MONTABON, F., AND CALANTONE, R. (1999), "Integrating Environmental Issues into Material Plannning: "Green" MRP." *Production and Inventory Management Journal*, 40, 3, 36-43.
MEYER, C. (1993)., *Fast Cycle Time: How to Align Purpose, Strategy, and Structure for Speed*. The Free Press, New York, NY.
MILES, M., AND HUBERMAN, A. (1994), *Qualitative Data Analysis: A Sourcebook of New Methods.* Sage Publications, Newbury Park, CA.
MOORE, A. G. (1991), *Crossing the Chasm: marketing and selling technology products to mainstream customers*. Harper Business.
MURRY, K. B. AND MONTANARI, J. R. (1986), Strategic Management of the Socially Responsible Firm: Integrating Management and Market Theory. *Academy of Management Review*, 11, 815-827.
PATTERSON, M.L. (1993), *Accelerating Innovation: Improving the Process of Product Development.* Van Nostrand Reinhold, New York, NY.
PAVA, M., AND KRAUSZ, J., (1996), The Association Between Corporate Social Responsibility and Financial Performance: The Paradox of Social Cost, *Journal of Business Ethics*, 15, 321-375.
PEATTIE, K. (1992), *Green Marketing*, Longman Group, London, UK
PETERAF, M., (1993), The Cornerstone of Competitive Advantage: A Resource-Based View. *Strategic Management Journal*, 13, 363-380.
PINE II, B. (1993), *Mass Customization: The New Frontier in Business Competition*. Harvard Business School Press, Cambridge, MA.
POLONSKY, M. AND OTTMAN, J. (1998), "Stakeholders contribution to the green new product development process", *Journal of Marketing Management*. 14, 533 – 557.
POLONSKY, M. ROSENBERGER, P., AND OTTMAN, A. (1998), "Developing green products: learning from stakeholder", *Journal of Sustainable Development*, 1, 5, 7-21.
PORTER, M.E., AND VAN DER LINDE, C. (1995a), "Green and Competitive -- Ending the Statement." *Harvard Business Review*, September-October, 120-134.
PORTER, M.E., AND VAN DER LINDE, C. (1995b), "Toward a New Concept of the Environment-Competitive Relationship." *Journal of Economic Perspectives*, 9, 4, 97-118.
POST, J.E. (1991), "Managing as if the Earth Mattered," Business Horizons, 34, 4, 32-38.
RONDINELLI, D. A., AND VASTAG, G. (1996), "International Environmental Standards and Corporate Policies: An Integrative Framework." *California Management Review*, 39, 1, 106-122.
ROYSTON, M. G. (1980), "Making Pollution Prevention Pay," Harvard Business Review, November-December, 6-22.
RUMELT, R. (1984), Towards a strategic theory of the firm, in R. Lamb (ed). *Competitive Strategic Management*, Englewood Cliffs, NJ: Prentice-Hall. 556-570.
RUSSO, M. V., AND FOUTS, P. A., (1997), A Resource-Based Perspective on Corporate Environmental Performance and Profitability, *Academy of Management Journal*, 40, 3, 534-559.
SARKIS, J., AND RASHEED, A. (1995), "Greening the Manufacturing Function," *Business Horizons*, September-October, 17-27.
SHARMA, S., S. DURVASULA, AND W.DILLON (1989), "Some Results on the Behavior of Alternate Covariance Structure Estimation Procedures in the Presence of Nonnormal Data," *Journal of Marketing Research*, 26, 214-221.
SHRIVASTAVA, P. (1995), "Environmental Technologies and Competitive Advantage," *Strategic Management Journal*, 16, 221-238.
SROUFE, R., CURKOVIC, S., MONTABON, F., AND MELNYK, S. (2000), "The New Product Design Process and Design for Environment: Crossing the Chasm," *International Journal of Operations and Production Management*, 20, 2, 267-291.
STALK, G. JR., AND HOUT, T. (1990), *Competing Against Time*. The Free Press, New York, NY.
STARIK, M., AND RANDS, G. P. (1995), Weaving an Integrated Web: Multilevel and Multisystem Perspectives of Ecologically Sustainable Organizations. *Academy of Management Review*, 20, 908 - 935.
TIBOR, T. AND FELDMAN, I. (1996), *ISO 14000 A Guide to the New Environmental Management Standards*. Irwin, 1996.

ULRICH, K. AND PEARSON, S. (1993), “Does product design determine 80% of manufacturing cost?” *MIT Sloan School Working Papers*.
WADDOCK, S., AND GRAVES, S. (1997), “The Corporate Social Performance – Financial Performance Link.” *Strategic Management Journal*. 18: 303 - 319.
WALLEY, N., AND WHITEHEAD, B., (1994), “Its Not Easy Being Green,” *Harvard Business Review*, May-June, 46-52.
WHEELER, D. AND AFSAH, S. (1996), “Going Public on Polluters: Indonesia’s New Program.” *Asian Executive Reports*, 18, 9, 9
WILLIAMS, M., (1991)., Using Cross-Functional Teams to Integrate Environmental Issues into Corporate Decisions.” *GEMI Conference Proceedings, Corporate Quality/Environmental Management, The First Conference,* Washington DC: Global Environmental Management Initiative, pp. 139-142.
WILLIAMS, L.J., AND HAZER, J.T. (1986), “Antacedents and Consequences of Organizational Tournover: A Reanalysis using Structural Equations Model.” *Journal of Applied Psychology*, 71 (May) 219-231.
WOOD, D.J., (1991), “Corporate Social Performance Revisited.” *Academy of Management Review*, 16, 4, 691-718.

APPENDIX 1 FINAL CONSTRUCTS AND MEASURES

(F1) Environmental Management Systems

- Emsdoc: EMS procedures are formally documented
- Emsformal: your company has a formal EMS
- Emsdept: formal department responsible for environmental affairs
- Emscirc: EMS procedures are widely available
- Emsrpt: formal reporting position between environmental group and executives
- Emseperf: environmental performance formally tracked and reported
- Emsvis: top management support for environmental performance
- Emseinf: environmental information is tracked and monitored regularly
- Emssumm: environmental performance is periodically captured and summarized
- Emstrain: environmental issues, policies, and procedures are included in training
- Emsgoals: goals have been developed and implemented which report environmental performance
- Emspos: environmental position is given prominent visibility in annual report
- Emsineff: people within firm consider EMS highly effective
- Emsdata: firm has a well developed EMS data base for tracking and monitoring environmental issues
- Emsoutef: people outside the firm consider the EMS highly effective
- Emsdist: environmental performance results widely distributed
- Emscause: causes of environmental problems are focused on
- Emsachv: environmental achievements given visibility in annual reports
- Emsreasn: reasons for environmental problems are attacked

No measures were dropped for this construct

(F2) Design Practices

- Optproc: process redesign
- Optprod: product redesign
- Optreduce: reduce
- Optsub: substitution
- Optdis: disassembly
- Optrecycle: recycle

No measures were dropped for this construct

(F3) Manufacturing Practices

- Optreman: remanufacture
- Optrebld: rebuild
- Optproln: prolong use
- Optconsm: consume internally

One measure was dropped for this construct

(F4) Waste Practices

- Optseg; waste segregation
- Optcreat: creating a market for waste products
- Optreloc: relocation
- Optspred: spreading risk
- Optrepck: returnable packaging

One measure was dropped for this construct

(F5) Operations Performance (environmental activities have:)

- Actqual: significantly improved quality
- Actcost: significantly reduces costs
- Actbene: benefits outweigh costs
- Actpos: improved position in marketplace
- Actprods: design/develop better products
- Actwprod: reduces waste in production processes
- Actwequip: reduced waste within equipment selection
- Actinter: improved changes of selling products in international markets
- Actis: reasonable demands on IS and data requirement

Four measures were dropped for this construct