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EFFECTS OF ENVIRONMENTAL MANAGEMENT SYSTEMS ON ENVIRONMENTAL MANAGEMENT PRACTICES AND OPERATIONS*

ROBERT SROUFE
The Wallace E. Carroll School of Management, Operations and Strategic Management Department, Boston College, 140 *Commonwealth Avenue, Chestnut Hills, Massachusetts* 02467

To date, it is unclear as to how Environmental Management Systems (EMS) are implemented and what effects these systems have on other environmental and operational practices. This study reports empirical insights to EMS practices based on the largest EMS survey of manufacturing firms in the United States. The objective of the study is to test for a relationship between environmental management systems and perceived operations performance while considering direct and indirect effects of various environmental practices. The results of this study are supported by several field studies and provide a new source of information regarding EMS theory development. The results also indicate a positive relationship between an EMS, the environmental practices a firm engages, and operations performance measures.
(ENVIRONMENTAL MANAGEMENT SYSTEMS; ENVIRONMENTAL PRACTICES; ENVIRONMENTAL PERFORMANCE; MULTIMETHODS; STRUCTURAL EQUATION MODELING)

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, changing customer demands, and managers recognizing pollution as waste (Kleiner 1991; Porter and Van Der Linde 1995), 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.

In this study, I further develop one component of Klassen and Whybark's (1999a and 1999b) environmental technology portfolio by examining reported environmental business practices, developing links with other environmental practices, and gain an understanding of

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the relationship between an EMS and perceived impacts on performance. The objectives of this study do not include a formal assessment of ISO 14001 certification. Instead, I review and discuss an environmental management system construct. Next, model development is discussed and environmental management practices are defined in terms of design, recycling, and waste practices. This new EMS construct is expected to have implications for both environmental and operations performance. Finally, the empirical relationships between an EMS, environmental practices, and operations are assessed by using a sample of manufacturing plants from the United States.

2. Model Development

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 which include different practices found within the environmental technology portfolio in pollution prevention technologies, management systems, and pollution control technologies (Klassen and Whybark 1999a and 1999b). Therefore, environmental projects affect all of the functional areas of a business enterprise (Kleiner 1991). For the purpose of this study, environmental practices are broken down into design, recycling, and waste practices. It is early in design practices that decisions are made that impact operations practices and set into place the actions that ultimately create waste streams encountered in the transformation system. One way of controlling and reducing environmental waste is to integrate systems and practices to achieve better environmental performance.

There are many reasons why EMSs should be potentially attractive to management. First, there is the increasing use of voluntary EMS standards available to help guide development of these types of systems. These standards include the United Kingdom's BS 7750, and in the United States the NSF International's 110 EMS standard, the American National Standards Institute and American Society for Quality Control (ANSI/ASQC) E4 standard, and ISO 14001. Second, there is the potential of an EMS becoming important to supply chain members (Rondinelli and Vastag 1996). Third, the potential of pollution prevention leading to reduced costs of production and higher profits (Makower 1994; Russo and Fouts 1997). Fourth, the increased importance of corporate social responsibility (Wood 1991; Pava and Krausz 1996; Waddock and Graves 1997). Finally, the development of an EMS may provide firms with a unique environmental resource, capabilities, and benefits that may lead to competitive advantage (Rumelt 1984; Klassen and Whybark 1999b; Hart 1995; Starik and Rands 1995). While the potential benefits are numerous, there is still a dearth of research that empirically tests EMS relationships.

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 also help companies affect a culture change as environmental management practices are incorporated into its overall business operations. The assumption is that better environmental management will lead to better performance (Dechant and Altman 1994).

To the extent that a firm has an EMS, such a system should facilitate better cross-functional integration of resources and information to facilitate other environmental practices within the firm. Thus, the first hypothesis in this study involves the relationship of an EMS to the environmental management practices in which a firm engages. (See Figure 1 for the Conceptual Model, and Appendix 1 for a list of all constructs and measures used in this study.)

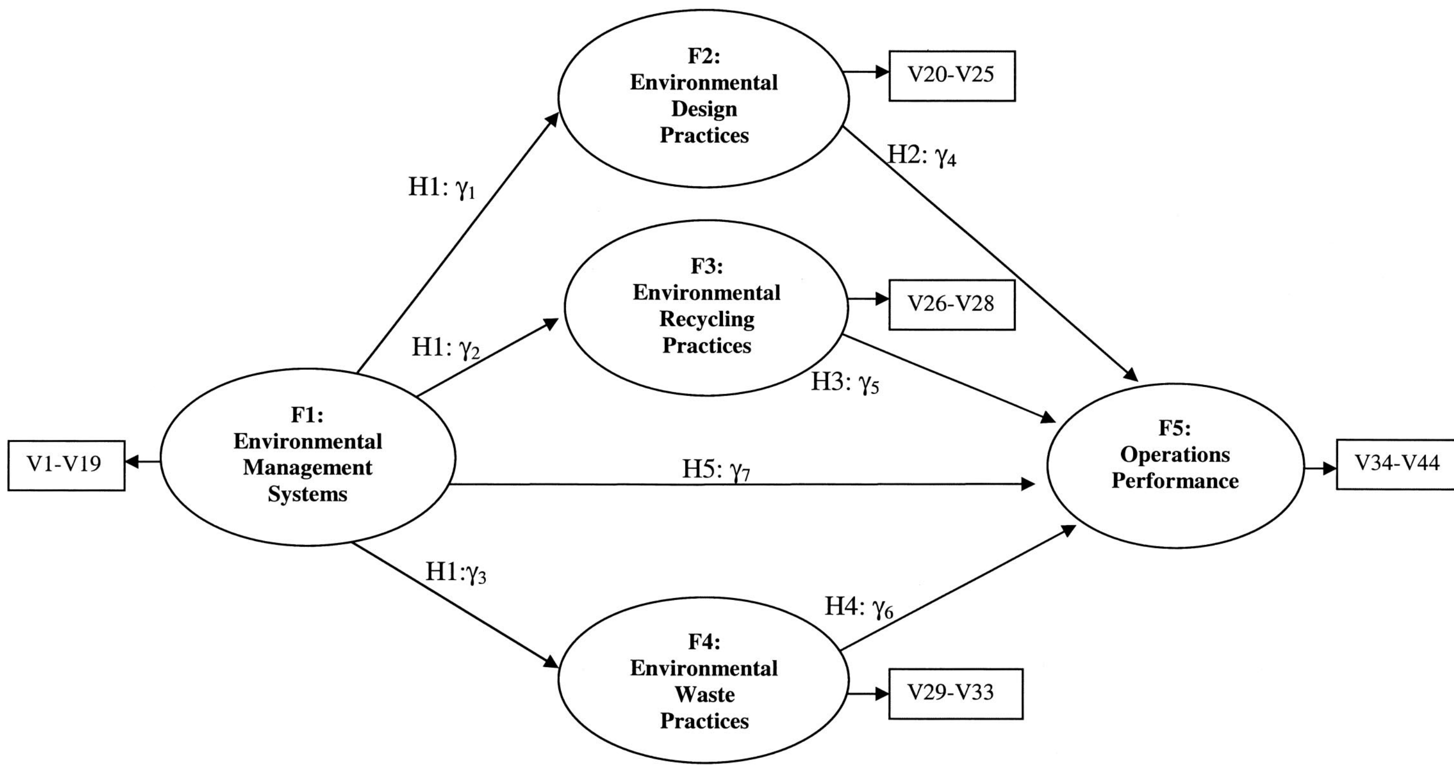

FIGURE 1. Conceptual and Structural Model. F1: Environmental Management System. F2: Environmental Design Practices. F3: Environmental Recycling Practices. F4: Environmental Waste Practices. F5: Perceived Operations Performance. H1—H5: Hypotheses. γ_1 to γ_7: Estimated Path Coefficients. V1—V44: Variables used per construct. Note: 27 error terms in measurement model and 5 error terms in the structural model are not shown.

HYPOTHESIS 1. *The degree to which a firm is involved in EMS activities is positively related to the degree to which it is involved in environmental practices.*

2.1. *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 practices considered by a firm when facing environmental design, recycling, or waste reduction initiatives.

2.1.1. ENVIRONMENTAL DESIGN PRACTICES. The New Product Development (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 (Patterson 1993) due to increased market pressures to reduce lead time, reduce cost, enhance product flexibility, and improve product quality.

Much of the prior research attention has been focused on product/process design (Allenby 1993), and the use of "green" design initiatives has been increasing (BSR 1998). Design activities, in general, present opportunities for firms to find solutions to environmental issues (Lozada and Mintu-Wimsatt 1995). 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). For the purpose of this study, environmental design practices include substitution, reduction, redesign, design for disassembly, and using recycled materials. Given the importance of 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 several performance measures.

HYPOTHESIS 2. *The degree to which a firm is involved in environmental design practices is positively related to firm performance.*

2.1.2. ENVIRONMENTAL RECYCLING PRACTICES. McKinsey and Company (1991) found production and operations as being a major part of a firm's ability to meet 50% waste reduction goals. Additionally, Klassen (2000) found a link between advanced manufacturing practices, pollution prevention, and operations. Implicitly included in the before-mentioned studies are the concepts such as rebuilding and remanufacturing. These recycling practices are an attempt to provide greater value to customers with fewer materials. Recycling practices, as operationalized for this study, include rebuilding a product where some of the parts or components are recovered while others are replaced; remanufacturing, where a product's primary components come from used products and the consumption of scrap and typical waste materials internally.

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 such as recycling. Therefore, environmental recycling practices should have a positive impact on performance.

HYPOTHESIS 3. *The degree to which a firm is involved in environmental recycling practices is positively related to firm performance.*

2.1.3. ENVIRONMENTAL 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. Additional support for this approach to cost reduction and waste management is found in Hart and Gautam (1996), who find a link between emission reductions and firm performance.

Based on the findings of previous research, environmental systems should impact environmental waste practices 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 returnable packaging. These waste-related practices involve innovations that lower the total cost of a product or improve its value, thus offsetting the costs of improving environmental impact as suggested by Porter and Van Der Linde (1995). A company's ability to accurately reflect the costs associated with products and processes is critical 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, make managers involved in decisions about waste management more informed.

HYPOTHESIS 4. *The degree to which a firm is involved in environmental waste management practices is positively related to firm performance*.

2.2. *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. The benefits and theoretical linkages of the proposed conceptual model in Figure 1 are based on the resource-based view of the firm and the natural resource based-view of the firm.

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). From an environmental perspective, unique resources help integrate environmentally oriented interactions with other levels and systems, internal and external to the firm (Starik and Rands 1995), and Hart (1995) argues that businesses are dependent on ecosystems and ecologically sustainable activities. Within this dynamic environment, an EMS can provide information used to aid decision making and the allocation of scarce resources, provide internal and external reporting information, or if certified to a public standard, can facilitate entry into markets having environmental restrictions. Thus, an EMS can provide specialized information and enhance performance.

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. *The degree to which a firm is involved in EMS activities is directly and positively related to firm performance*.

3. 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; Clark, Stavins et al. 1994; Clarke, Cairncross et al. 1994; Porter and Van Der Linde 1995).

To increase face validity, the research questionnaire was developed and pretested by 15 respondents in a 3-round process over a period of 2 months. This group represented a variety of positions and functions within their firms in a variety of industries. To facilitate content validity, the 16-page survey with 250 items was developed after a thorough literature review with the goal of establishing measures for new environmental concepts. The full survey, field notes, and complete sample information are available in Melnyk et al. (1999).

In addition to the survey, field-based data collection methods were used at eight manufacturing facilities to ensure that important variables were captured during the interview process. These methods also helped develop an understanding of why new variables might be important (Eisenhardt 1989). A small detailed sample fit the needs of the research and complemented the large-scale survey. The method followed was similar to grounded theory development as suggested by Glaser and Strauss (1967), Eisenhardt (1989), and Miles and Huberman (1994).

To facilitate a large-scale survey, 3 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 14001 for manufacturing firms within the United States. Of the 15,000 questionnaires mailed, 1,510 questionnaires were returned constituting a response rate of over 10% with the level of analysis for this study being manufacturing firms at the plant level. The single most serious limitation to direct mail data collection is a relatively low response rate. Large-scale survey response rates are often only about 5–10% (Alreck and Settle 1995). The majority of respondents were managers, with over 60% of the respondents indicating involvement in environmental planning and management activities within their firms, and over 65% indicating involvement in environmental regulatory compliance initiatives.

While it is possible to pursue scale development and verification of the validity of the measurement model using all respondents, I instead choose to control for some industry differences and use respondents with complete data for all applicable responses. After eliminating non-manufacturing industries, the data set included 1,331 respondents. Listwise deletion then brings the sample size down to 1,118. The mean sales for the resulting sample was $962 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 for 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 by 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 significant differences. Based on Armstrong and Overton (1977), the findings suggest that non-response bias is not a problem in this study.

4. Data Analysis

Structural Equation Modeling (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 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 by using chi-square and other tests, which are available in EQS. To date, the most widely used fitting function for structural equation modeling is the Maximum Likelihood (ML) function (Bollen 1989). Due to nonnormality indicators, specifically a high positive Mardia's coefficient, Elliptical Reweighted Least Squares (ERLS) was used for 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 1) is estimated. The rationale of this approach is that accurate representation of the reliability of the indicators is best accomplished in two stages to avoid the interaction of measurement and structural models (Hair, Anderson, Tatham, and Black 1999). When faced with measures that are less reliable, or theory that is only tentative, researchers should consider a staged approach to maximize the interpretability of both the measurement and structural models. The following sections of this study discuss the results of the structural equation modeling two-stage process.

5. Results

In the first stage, the measurement properties were first assessed by testing a hypothesized measurement model much the same as using a confirmatory factor analysis (CFA). While environmental research in business is relatively novel, a strong *a priori* basis for the proposed model warranted the use of confirmatory factor analysis rather than an exploratory factor analytic approach. A CFA is a more rigorous method for assessing unidimensionality when compared with 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.

A widely used statistic for assessing overall fit is the chi-square statistic. It has been widely noted that there are problems with the chi-square test (Bentler and Bonett 1980; Steiger and Lind 1980). One of the concerns has centered on the sample size issue. With the increased statistical power of the test afforded by a large sample, a trivial difference between the sample covariance matrix S and the fitted model $\hat{S}$ may result in rejection of the specified model. Furthermore, the chi-square may not be chi-square distributed when the typical underlying assumption of multivariate normality is violated (Hoyle 1995). The approach taken for this study is that the use of multiple fit criteria, such as 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).

5.1. *Testing the Hypothesized Measurement Model*

Initial testing of the hypothesized model yielded good fit indices (i.e., above 0.95) (see Table 1) and a slightly higher than desired 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 (Hair et al. 1999). The standardized solution of the final measurement model with factor loadings and R-squared is given in Table 2.

TABLE 1

Goodness-of-Fit Summary for the Measurement Model

Degrees of freedom (df)	892
Sample Size	1118
Chi-squared value	7916
p-value	<0.01
Bentler-Bonnett Normed Fit Index (NFI)	.962
Bentler-Bonnett Nonnormed Fit Index (NNFI)	.964
Comparative Fit Index	.966
Standardized RMR	.050

TABLE 2

Standardized Solution

STANDARDIZED SOLUTION:			R-SQUARED
EMSDOC=	.855*F1	+.519 E1	.730
EMSFORML=	.844*F1	+.536 E2	.712
EMSDEPT=	.782*F1	+.623 E3	.612
EMSCIRC=	.822*F1	+.569 E4	.676
EMSRPT=	.796*F1	+.605 E5	.634
EMSEPERF=	.916*F1	+.401 E6	.840
EMSVIS=	.850*F1	+.527 E7	.722
EMSEINF=	.847*F1	+.532 E8	.717
EMSSUMM=	.909*F1	+.417 E9	.826
EMSTRAIN=	.845*F1	+.535 E10	.714
EMSGOALS=	.918*F1	+.397 E11	.843
EMSPOS=	.839*F1	+.544 E12	.704
EMSINEFF=	.848*F1	+.530 E13	.719
EMSDATA=	.856*F1	+.517 E14	.733
EMSOUTEF=	.812*F1	+.583 E15	.660
EMSDIST=	.862*F1	+.507 E16	.743
EMSCAUSE=	.715*F1	+.699 E17	.511
EMSACHV=	.819*F1	+.574 E18	.671
EMSREASN=	.687*F1	+.726 E19	.473
OPTSUB=	.834*F2	+.552 E23	.695
OPTREDUC=	.875*F2	+.483 E24	.766
OPTPROC=	.822*F2	+.569 E25	.676
OPTPROD=	.783*F2	+.622 E26	.613
OPTDIS=	.753*F2	+.658 E27	.568
OPTRECYC=	.712*F2	+.703 E28	.506
OPTREMAN=	.795*F3	+.607 E35	.632
OPTREBLD=	.826*F3	+.563 E36	.682
OPTCONSM=	.608*F3	+.794 E38	.370
OPTSEG=	.667*F4	+.745 E29	.444
OPTCREAT=	.700*F4	+.714 E30	.491
OPTRELOC=	.562*F4	+.827 E31	.316
OPTSPRED=	.574*F4	+.819 E33	.329
OPTREPCK=	.622*F4	+.783 E34	.387
ACTQUAL=	.869*F5	+.494 E39	.756
ACTLT=	.808*F5	+.590 E40	.652
ACTPOS=	.869*F5	+.495 E41	.755
ACTPRODS=	.838*F5	+.546 E42	.702
ACTCOST=	.795*F5	+.606 E43	.633
ACTWEQIP=	.803*F5	+.596 E44	.645
ACTINTER=	.760*F5	+.650 E45	.578
ACTREP=	.815*F5	+.580 E46	.664
ACTWPROD=	.779*F5	+.628 E47	.606
ACTBENE=	.759*F5	+.651 E48	.576
ACTIS=	.678*F5	+.735 E49	.460

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

Degrees of freedom (df)	895
Sample Size	1118
Chi-squared value	8444
p-value	<0.01
Bentler-Bonnett Normed Fit Index (NFI)	.959
Bentler-Bonnett Nonnormed Fit Index (NNFI)	.961
Comparitive Fit Index	.963
Standardized RMR	.075

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. Two of the original 46 measures were dropped before completing the CFA model. The measures dropped because of cross loading on other factors and high covariance among residuals include 1 environmental manufacturing practice for prolonging the overall life of the product and 1 waste practice in which alliances are formed with customers and supply chain members to address environmental issues. The measurement model was run by using both ML and ERLS estimation. The ERLS results for the measurement model are displayed in Table 3.

The measurement model yielded a $\chi^2 = 7{,}916$, with 892 degrees of freedom and fit indices NFI, NNFI, and CFI all above 0.96. With the exception of the p-value for the χ^2, multiple goodness of fit indices indicate a well-fitting model. With the χ^2 statistic strongly influenced by sample size, the low p-value was not seen as a single limiting factor for the model since at larger sample sizes, power is so high that even models with only trivial misspecification are likely to be rejected (Hoyle 1995). Additional support for model fit is found in low residuals with a standardized RMR of 0.05 and construct reliabilities for all constructs above 0.70 (Hair et al. 1999). Reliability measures the extent to which a measurement scale yields consistent results on repeated replications of the same scale. After assessing the internal consistency of the items within each scale using both Cronbach's alpha and the construct reliability measures (Hair et al. 1999), the scales comprising each of the 5 factors were internally consistent and sufficiently reliable with measures ranging from 0.71 to 0.97.

Content validity required that scales measure what they are supposed to measure and nothing else (Flynn et al. 1990). This also involves the domain of meaning comprising the scale (Churchill 1979) and, as previously discussed, was assessed through interaction with manufacturing managers. This is a nonstatistical assessment of validity, which is supported by expert judgment and a thorough literature review. Convergent validity is assessed by verifying whether each indicator's estimated path coefficient on its hypothesized underlying construct factor is significant (Anderson and Gerbing 1988). In this study, a good degree of convergent validity was found since all factor loadings were statistically significant and positive. The overall validity of the model was tested by using multiple fit criteria and found to be sufficiently good. If either the χ^2 goodness-of-fit test or fit indices indicate acceptable overall fit of a specified model, then the focus moves to the full model.

5.2. *The Full Structural Equation Model*

The full structural equation model in Figure 1 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 γ_1 through γ_7).

TABLE 4

Measurement Equations with Standardized Errors and Test Statistics

Hypothesis: Regression from	Coefficient to	Parameter Estimate	Standard Error	t-value*
H1: EMS	Design Practices	$\gamma_1 = .630$	.030	20.979
H1: EMS	Recycling Practices	$\gamma_2 = .455$	.033	13.759
H1: EMS	Waste Practices	$\gamma_3 = .515$	.031	16.402
H2: Design Practices	Operations Performance	$\gamma_4 = .212$	.032	6.583
H3: Recycling Practices	Operations Performance	$\gamma_5 = .076$	.027	2.777
H4: Waste Practices	Operations Performance	$\gamma_6 = .235$	.046	5.143
H5: EMS	Operations Performance	$\gamma_7 = .250$	.039	6.430

*, All parameter estimates are significant at the $p < 0.01$ level.

The structural component of the model in Figure 1 represents the hypothesis that an EMS (F1) indirectly influences the different practices a firm may engage in, such as design, recycling, 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 by using both ML and ERLS. Estimation results for the full model are given in Table 4. ERLS estimation of the full model resulted in a $\chi^2 = 8{,}444$, 895 degrees of freedom, and fit indices for NFI, NNFI, and CFI all above 0.95. Given the large sample size, it is not surprising to find a high chi-square statistic and low p-value. Based on the goodness-of-fit statistics, there is a good degree of fit in the posited model. Additional support for the fit indices is the large amount of statistical power demonstrated by this model having such a large sample size and high degrees of freedom (McCallum, Browne, and Sugawara 1996). The results of the full model and significant positive path coefficients for γ_1 through γ_7 support Hypotheses 1 through 5.

The measurement model has adequate fit with the data relative to the early stages of construct development in this field and the large sample size used in this study. The data also fit the full structural equation model well with multiple fit indices over 0.95 and an error term of 0.075. The fit indices of the full model exceed the levels of 0.95 suggested by Bentler (1989) for confirmed models.

6. Discussion

With definitional ambiguity leaving practitioners with few frameworks and insights, researchers need to understand how to measure and operationalize the EMS construct. Little empirical research exists as to what the defining attributes of an EMS are, or how EMSs are linked to environmental practices and performance. The development of a new EMS construct contributes to theory development in the growing field of environmental management and operations and provides a better understanding of what constitutes an EMS, what environmental practices plants are engaged in, and where scarce resources should be allocated.

EMS construct development is based on the literature review, field studies, experiences of the researcher, perceptions of the respondents, and 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 19 manifest variables comprising the latent EMS construct. Additional analysis using a standardized coefficient alpha for the 19 manifest variables used in the EMS construct results in a 0.977 for this summated scale. As a result of the analysis and for the purpose of clarification and further discussion, an EMS involves the following: a 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, recycling, 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 hypotheses involving the relationship of an EMS to environmental practices and performance and support the findings with a brief summary of several field studies.

6.1. *Discussion of Statistical Results*

HYPOTHESIS 1. The more a firm is involved in EMS activities, the stronger the positive relationship between this system and environmental practices. 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 0.630, p-value < 0.01 for the relationship to design; $\gamma_2 = 0.455$, p-value < 0.01 for the relationship to recycling practices; and $\gamma_3 = 0.515$, p-value < 0.01 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 presence of a formal EMS, top management support for the system, the documentation, tracking and reporting of environmental information, use of performance goals, training, and internal and external perceptions of the system. The EMS construct has strong relationships to environmental design, recycling, and waste practices as posited.

HYPOTHESIS 2. The more a firm is involved in environmental design practices the stronger the positive relationship to firm performance; $\gamma 4 = 0.212$, p-value < 0.01. This relationship is relatively weak, 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.

HYPOTHESIS 3. The more a firm is involved in environmental manufacturing practices the stronger the positive relationship to performance; $\gamma_5 = 0.076$, p-value < 0.01. This relationship between manufacturing practices and performance is attenuated due to a narrowly defined construct, including rebuilding, remanufacturing, and the consumption of waste internally, and is not as strong as hoped.

The low path coefficient for γ_5 is one of the interesting findings of this study, but may not be that surprising given the narrowly defined latent variable for environmental recycling practices and the relatively small amount of remanufacturing and rebuilding done by firms. The results support the idea that these narrowly defined environmental recycling practices have a low impact on the strategic dimensions of the plant and the impact of these practices may be more tactical in nature. Further examination of this construct and relationships to environmental practices and performance is warranted.

HYPOTHESIS 4. The more a firm is involved in environmental waste practices the stronger the positive relationship to performance; $\gamma_6 = 0.235$, p-value < 0.01. This provides evidence that better management of waste should have positive impacts on firm performance even though the coefficient is low.

As evident from the SEM results and Hypotheses 1 through 4, an EMS is indirectly related to performance through the environmental practices the firm is involved in. This lends support to Tibor and Feldman's (1996) claim that environmental management will lead indirectly to better environmental performance and is also supported by the resource-based view of the firm. Tibor and Feldman's premise is that improved systems associated with EMSs (e.g., those used in design, manufacturing, and waste practices of plants) will make achievement of performance goals more likely.

Additionally, the field studies support the overall findings that EMSs are indirectly related to enhanced operations performance. Plants in this study were finding many hidden environmental costs, and these costs can now be tracked, managed, and reduced while giving more leverage to the environmental practices of the firm.

HYPOTHESIS 5. An EMS is directly related to performance; $\gamma_7 = 0.250$, p-value < 0.01. There is a significant and positive relationship between a plant's EMS and performance. Based on the measures used for each construct, there is a direct relationship between a plant's 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, costs, and position in the marketplace, bringing about better products, equipment selection decisions, reducing waste in production, improving chances of selling products in international markets, and has benefits that outweigh the costs.

While a previous study involving this data set suggested relatively low impacts of environmental systems on performance, that conclusion was based on descriptive statistics compared across variables and did not test multivariate relationships. Results of this study indicate that an EMS is related to more than just environmental performance in that these types of systems help improve products and plant image, reduce costs, and also improve quality. Conversations with managers from one of the firms in this study demonstrated that the environmental department within the plant could leverage their position as a "benefit and not a cost" to the organization.

7. Field Studies

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. While this study focuses primarily on the survey data, the research project that generated the quantitative and qualitative data attempted to overcome the deficiencies of any one approach by using a triangulated approach. The field studies were part of a larger research project, and more detailed information including the protocol and firms studied can be found in Melnyk et al. (1999).

In general, the SEM results are echoed by the field studies. The field studies show that, for the firms involved in EMS development, or certification, these firms focused on some design, waste, and performance measures, while largely overlooking recycling practices. Given this, the firms in this study were not measuring, monitoring, or managing environmental manufacturing and recycling 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. Thus, firms may focus more on corporate social performance and outputs such as waste reduction (Wood 1991; Pava and Krausz 1996). The findings suggest that operations managers may be cautious when engaging in environmental operations practices as defined in this study. Additionally, the allocation of scarce resources among competing environmental practices typically goes toward either design or waste initiatives.

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 demonstrate the importance of an EMS to the environmental technology portfolio. An EMS has many impacts on environmental management and on operations. There appears to be a need to expand the environmental technology portfolio to include a more rigorous definition and measurement of management systems. Additionally, there is a need to better understand how firms integrate EMSs into existing operations processes and how formal certification of these systems further impacts environmental management and operations.

8. Conclusions

For an EMS to be effective, it should be involved in the monitoring, tracking, summarizing, and reporting of environmental information to internal and external stakeholders. 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 specialized procedures and information to be available to people in new product development, recycling, and pollution prevention. 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 initiatives.

The research conducted in this study did not take on an exploratory approach. Instead, a confirmatory factor analytic approach was used to develop and test a relatively complex nomological network supported by the literature and several field studies. The results suggest that environmental recycling practices (as defined in this study) tend to have a low impact on performance, while environmental management systems directly, and indirectly through environmental design practices and environmental waste practices, have a higher impact on firm performance.

One of the goals of this study 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 EMS variable. Theory building is supported through the explanatory and predictive powers of the model. Future research should be directed at the effects of different management levels and industries on the relationships found in this study. Additionally, collection of information from key respondents involved only in Environmental Health and Safety responsibilities at the plant level can provide unique insights not captured within other cross-functional areas of a manufacturing facility.[1]

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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

(F2) Design Practices
- Optsub: substitution
- Optreduce: reduce
- Optproc: process redesign
- Optprod: product redesign
- Optdis: disassembly
- Optrecycle: recycling

(F3) Recycling Practices
- Optreman: remanufacture
- Optrebld: rebuild
- Optconsm: consume internally

(F4) Waste Practices
- Optseg: waste segregation
- Optcreat: creating a market for waste products
- Optreloc: relocation
- Optspred: spreading risk
- Optrepck: returnable packaging

(F5) Operations Performance (environmental activities have:)
- Actqual: significantly improved quality
- Actlt: significantly improved lead time
- Actpos: improved position in marketplace
- Actprods: design/develop better products
- Actcost: significantly reduces cost
- Actwequip: reduced waste within equipment selection
- Actinter: improved chances of selling products in international markets
- Actrep: enhanced reputation
- Actwprod: reduces waste in production processes
- Actbene: benefits outweigh costs
- Actis: reasonable demands on IS and data requirement

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Robert Sroufe is an Assistant Professor of Operations Management in the department of Operations and Strategic Management at the Wallace E. Carroll School of Management, Boston College. Robert's research is primarily focused on environmental management systems and his interests include environmentally responsible manufacturing, green supply chain management, green purchasing, and performance metrics. Robert's current research efforts are sponsored by KPMG and with coauthors Frank Montabon and Ram Narasimhan is a two time recipient of the best environmental issues paper award at Decision Sciences.