Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Operations Management 21 (2003) 329–351
JOURNAL OF OPERATIONS MANAGEMENT
www.elsevier.com/locate/dsw

Assessing the impact of environmental management systems on corporate and environmental performance

Steven A. Melnyk [a,1], Robert P. Sroufe [b,*], Roger Calantone [a]

[a] *Department of Marketing and Supply Chain Management, The Eli Broad Graduate School of Management, Michigan State University, East Lansing, MI 48824-1122, USA*
[b] *Department of Operations and Strategic Management, Wallace E. Carroll School of Management, Boston College, Chestnut Hills, MA 02467-3808, USA*

Received 23 October 2000; accepted 2 September 2002

Abstract

There has been an increase in interest towards corporate activities aimed at reducing or eliminating the waste created during the production, use and/or disposal of the firm's products. Prior research has focused on the need for such activities, while current research tries to identify those components that encourage or discourage such activities. As a result of the introduction of ISO 14001, attention has turned to corporate environmental management systems (EMS). The underlying assumption is that such a system is critical to a firm's ability to reduce waste and pollution while simultaneously improving overall performance. This study evaluates this assumption. Drawing on data provided by a survey of North American managers, their attitudes toward EMS and ISO 14001, this study assesses the relative effects of having a formal but uncertified EMS compared to having a formal, certified system. The results strongly demonstrate that firms in possession of a formal EMS perceive impacts well beyond pollution abatement and see a critical positive impact on many dimensions of operations performance. The results also show that firms having gone through EMS certification experience a greater impact on performance than do firms that have not certified their EMS. Additionally, experience with these systems over time has a greater impact on the selection and use of environmental options. These results demonstrate the need for further investigation into EMS, the environmental options a firm chooses, and the direct and indirect relationships between these systems and performance.

Keywords: Environmental management systems; ISO 14001; Decision analysis; Regression; Empirical research; Survey

1. Introduction

Two areas of uncertainty are proving to be major obstacles to the widespread adoption of environmental practices by manufacturing firms and to the efforts of such firms to achieve ISO 14001 certification. The first stems from the ambiguity of the relationship between pollution reduction and profitability. The second arises from the lack of reliable information about the differences in tangible benefits derived from formal, certified environmental management systems (EMS) versus those from an informal or less rigorous set of environmentally focused activities. Consequently, the following question should be answered to help managers make sound decisions about the pollution reduction policies and practices of their firms: Do

* Corresponding author. Tel.: +1-617-552-0469; fax: +1-617-552-0433.
E-mail addresses: melnyk@msu.edu (S.A. Melnyk), sroufe@bc.edu (R.P. Sroufe), rogercal@msu.edu (R. Calantone).
[1] Tel.: +1-517-353-6381; fax: +1-517-432-1112.

0272-6963/02/$ – see front matter
PII: S0272-6963(02)00109-2

efforts aimed at reducing pollution impact operations performance and, if so, then does it matter whether the efforts meet ISO 14001 certification standards? The purpose of this study is to answer this pressing question.

A decade ago, there was virtually no debate in scholarly or manufacturing circles over the relationship between environmental practices and corporate performance. It was simply taken as a fact that pursuing environmental goals was antithetical to sound business strategy and, quite possible, a violation of the fiduciary duty of managers to shareholders. Conventional wisdom, in fact, held that any investment in improved environmental performance would contribute to penalties such as increased lead times, reduced quality or increased costs—all of which reduced profits and decreased returns to stockholders. In 1991, however, Porter challenged these entrenched beliefs and sparked a debate, which not only increased theoretical and practical interest in the possibility that profitability and pollution reduction were not mutually exclusive goals but, ultimately, brought about a dramatic shift in manufacturers' attitudes toward environmental responsibility (Porter, 1991).

According to Porter, pollution was simply waste, regardless of its source, which diminished value and was symptomatic of problems in products and/or processes. Therefore, contrary to received opinion, reducing or eliminating pollution/waste would not weaken but strengthen corporate competitiveness. Tradition dies hard, however, and Porter engendered criticism (Walley and Whitehead, 1994; Jaffee et al., 1993) as well as supportive efforts to expand upon his original position (Porter and Van der Linde (1995a,b) and several others (Bonifant and Ratcliff, 1994; Curkovic et al., 2000; Klassen and McLaughlin, 1996; Rothenberg et al., 2001; Montabon et al., 2000; Tibor and Feldman, 1996). In short, the debate continues, but not without positive effect. In the last 10 years, a radical change has come about in management's views on pollution, the need for pollution reduction and better environmental management. While the bastions of conventional thinking remain, they are decreasing in number, persuasiveness and political clout.

Into this continued questioning of the fundamental relationship between dollars and diminution of environmental destruction comes a new and virtually unresearched variable: ISO 14001 certification. In 1996, the ISO 14001 certification standards for environmental performance were adopted, with their acceptance predicated on the promise of certain benefits. First, ISO 14001 was argued to be the next logical step forward given the successes of the quality standard ISO 9000 and its automotive industry variant QS 9000 (Miles and Russel, 1997; Block, 1999; Caillibot, 1999; Reid, 1999; Corbett and Kirsch, 2001). Second, ISO 14001 was promoted as the standard that would replace the numerous and often conflicting sets of criteria found in various countries. Third, this new standard did not focus on outcomes such as reduced pollution. Instead, the focus of the standard is on the processes involved in the creation, management, and elimination of pollution. Basically, ISO 14001 was set forth as an effective tool to guide managers in their efforts to capitalize on the cost reduction potential of waste reduction (BSI, 1996). Fourth, supporters' lauded ISO 14001's stress on the crucial role played by an EMS in overall corporate performance (Sayre, 1996; Tibor and Feldman, 1996; Corbett and Kirsch, 2001). The impact on corporate performance is said to be an advantage of implementing a formal, certified environmental management system over those of pursuing a less stringent package of pollution-sensitive activities. This study assesses the impact of three types of EMS: (1) an informal system; (2) a formal system that does not meet ISO 1400 standards; and (3) a formal system that does meet ISO 14001 standards.

Since ISO 14001 has been in effect for 5 years, over 250,000 firms have been certified internationally (ISO World, 2000; ISO, 1999). The rate of certification is growing at least 50,000 per year (Corbett and Kirsch, 2001) and we even see large multinational Original Equipment Manufacturers (OEM) demanding certification of their supply base (Anonymous, 1999). Opportunities for research are now apparent through addressing the following questions: has ISO 14001 lived up to the promises made on its behalf and to those promises made on behalf of the adoption of a formal certified EMS? Until this study, little systematic research has been devoted to finding the answers to these questions. Other research questions involve the extent to which pollution reduction contributes to operations performance and the need to understand impacts of a formal, certified environmental management system, this study addresses three basic questions:

1. How does the presence or absence of a formal EMS affect both operations performance and environmental options?
2. Does a firm derive tangible benefits from having a formal, certified environmental management system?
3. What is the magnitude of the impact of (a) having a formal EMS and (b) having a formal and certified EMS?

These questions will be examined using a multimethod research perspective (Brewer and Hunter, 1989). Regression analysis of a survey database sheds light on EMS while simultaneously examining several posited relationships between formal EMSs and operations performance variables such as cost lead time, quality, flexibility, and enhanced reputation.

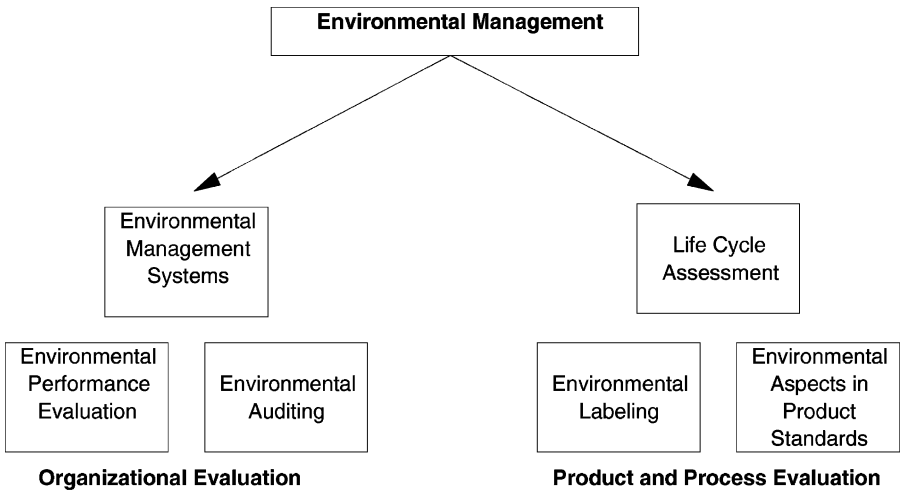
This paper is organized into four major sections: the first section establishes the concept of ISO 14001 and the EMS certification standard it sets forth. This discussion lays the groundwork for developing the concept of the EMS and its importance to the firm. The second section develops the operational framework for this study, while the third section summarizes the basic research design and statistical methodology used. To conclude, the fourth section presents the major findings and discusses the theoretical and research implications of the study before identifying directions for future research.

2. Understanding ISO 14001

In 1996, the International Organization of Standards adopted a new international standard for EMS–ISO 14001—with the intent not only of raising expectations for environmental practices worldwide but also to facilitate trade and reduce trade barriers. When properly implemented, ISO 14001 strives to meet these expectations, and to date, representatives from over 50 countries have formally adopted these standards.

More specifically, ISO 14001 encompasses the following general areas: EMS, auditing, performance evaluation, labeling, life cycle assessment, and product standards (Tibor and Feldman, 1996).

As shown in Fig. 1, these standards are divided into two general categories. The first consists of organizational evaluation, or the EMS and the auditing and performance standards used to evaluate the firm. In theory, the EMS standards provide the framework for the management system while the auditing and performance standards help evaluate and ensure the successful implementation of an EMS. The second category, product and process evaluation includes the



From Tibor and Feldman, 1996.

Fig. 1. ISO 14001 and environmental management systems.

labeling, life cycle assessment, and environmental attributes in product standards and focuses on the evaluation and analysis of product and process characteristics. Of these two categories, the first is currently the crux of the research presented in this paper.

But what exactly is an EMS? Based on our research efforts involving both field studies, survey data, and research with practitioners (Sroufe, 2000), an EMS involves 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. Building on this definition of an EMS, our study tests the relationship between this type of system, the environmental options a firm is involved in, and operations performance.

Of particular interest to this study, is the emphasis placed on the EMS. Arguably, this emphasis means the ISO 14001's developers recognized the critical role an EMS plays in any firm's attempts to reach the goals of improved environmental and corporate performance. This emphasis may even suggest that an EMS is so essential to environmental management that no firm can achieve competitive advantages unless it has an EMS in place that has met ISO 14001 certification standards.

Essentially, the ISO standards set forth the basic, structural elements of an EMS and, according to Tibor and Feldman (1996) and Sayre (1996) enable management to:

- Establish an environmental policy appropriate to the organization, including a commitment to the prevention of pollution.
- Facilitate planning, controlling, and monitoring to ensure policy is complied with and remains appropriate for the organization.
- Identify the legislative requirements and environmental aspects of the organization's products, services and activities to determine impact, significance, priorities, and objectives.
- Establish a program to implement these policies and objectives with a disciplined process of evaluating and achieving target performance levels while seeking improvements where appropriate.
- Develop management and employee commitment to the protection of the environment, with clear assignation of accountability and responsibility.
- Encourage environmental planning throughout the full range of the organization's activities, from raw materials acquisition to product distribution.
- Provide resources, including training, to achieve targeted performance levels on an on-going basis.
- Establish a management process to review and audit the EMS and to identify opportunities for improvement of the system and resulting environmental performance.
- Establish and maintain appropriate communications with relevant internal and external parties.
- Encourage contractors and suppliers to establish an EMS.

Importantly, however, the ISO 14001 EMS standards are process, not performance standards. In other words, these standards do not mandate a particular organization's optimum environmental performance level but describe a system to help an organization achieve its own environmental objectives. Underlying this approach is the assumption that by helping a firm focus on each stage of its manufacturing process, the firm will develop better environmental management practices and, ultimately improve its environmental performance.

3. Understanding the environmental management system

The purpose of an EMS is to develop, implement, manage, coordinate and monitor corporate environmental activities to achieve two goals: compliance and waste reduction (Sayre, 1996). For a firm, compliance simply means reaching and maintaining the minimal legal and regulatory standards for acceptable pollution levels for the purpose of avoiding sanctions. For example, failure to comply can result in increased costs (fines), increased external intervention in day-to-day operations, and, in extreme situations, issuance of

cease and desist orders. Clearly, waste reduction goes beyond compliance and focuses a firm's activities on the dramatic reduction of negative environmental impact. As compelling as these goals are, however, the extent to which EMS typically reach them has been relatively unexplored. So, too, the more fundamental question of what characteristics of an EMS must be present for a system to reach these goals remains virtually unresearched.

Though the concept and reality of EMS pre-dates the adoption of the formal ISO 14001 standard, researchers paid scant attention to the definition or study of these systems. It was not until 1996, that the International Organization for Standards released the standard and books condensing the standard appeared in the popular press.

4. EMS-developing the operational framework

The starting point for this study is the premise underlying much of the justification for the ISO 14001 environmental certification process—namely that the EMS plays a critical role in the firm's efforts not only to improve environmental performance but also overall performance. In this study, the impact between the EMS and operations performance can be conceptualized as taking place along two dimensions. The first dimension is that of operations performance.

For the purpose of this study, plant-level experts assessed the extent to which EMS impact different measures of operations performance. Operations performance, like the environmental options considered, consists of multiple measures. Some of the measures are strategically based. These measures focus on those elements of production competence (i.e. lead time, quality and cost) that generate value for the customer and that can create a strategic advantage for the firm (Vickery et al., 1993). Other attributes involve such areas as corporate reputation (Wood, 1991; Pava and Krausz, 1996), the ability to design and deliver better products and service (Sroufe et al., 2000), the ability to reduce waste and the relative costs/benefits associated with the initiatives. Basically, the presence of an EMS allows a firm to evaluate environmental performance against policy, objectives, and performance targets while seeking performance improvements where appropriate.

This study has not yet examined the impact of EMS certification. A firm's EMS can be envisioned as being in one of three possible states: (1) the firm does not have a formal EMS in place; (2) the firm has a formal EMS in place; or (3) the firm has a formal EMS in place that has been certified (through ISO 14001 certification). If the lack of a formal EMS represents the base case for the purposes of analysis, then each subsequent state can be viewed as representing an incremental improvement, which should build on the preceding stages. That is, a firm can choose to invest in implementing a formal EMS. Once such a system is in place, it can then chose to invest in having that system certified. In each case, the movement from one state to the next is posited to occur when marginal benefits exceed marginal costs. The presence of a formal and certified EMS should establish a system of operation, control and maintenance of the environmental program to ensure continuing high levels of overall system performance. In this study, the evaluation of the three states of an EMS (lack of formal, formal, and formal certified EMS) and any relationship to operations performance is carried out by means of the first hypothesis.

Hypothesis 1. Performance is lowest when EMS is not present, intermediate when EMS is present but not ISO 14001 certified, and highest when EMS is present and ISO 14001 certified.

The second dimension is the environmental options a firm can evaluate when contemplating how to reduce environmental emissions. Available to every manager are numerous options that can be chosen to improve performance and reduce pollution. Some of the more commonly considered environmental options are presented in Appendix A. While this list of options is by no means comprehensive, these options represent a wide variety of general and sometimes complex approaches. Alliances tend to be more complex than recycling because of the need to develop relationships that cross-corporate, not simply departmental boundaries. Options, such as recycling and waste separation, focus on reducing the "end of pipe" waste streams, while options such as product and process redesign focus attention on eliminating the pollution problem from occurring. Building on the cross-functional approach proposed by Cascio, 1996 and GEMI, 1996,

the presence of an EMS should encourage environmental planning throughout the full range of the organization's activities, from raw materials acquisition, through production, to product distribution. Thus, the presence of an EMS should result in a more extensive use of environmental options.

Hypothesis 2. Use of environmental options are lowest when a formal EMS is not present, intermediate when a formal EMS is present but not ISO 14001 certified, and highest when a formal EMS is present and ISO 14001 certified.

Of these two hypotheses, this study focuses primarily on the first. Hypothesis 1 examines whether the EMS and its stage of development has an impact on corporate performance. Hypothesis 1 is important in that it addresses in part an important question—that of whether there is a relationship between environmental and corporate performance. The second hypothesis, while important, can be viewed as secondary and as supportive of and influenced by the state of the EMS. The selection of options can be viewed as simply being a vehicle by which EMS affects corporate performance.

5. Other relevant variables

The discussion to this point has focused on the role of EMS in isolation. It has ignored the possible confounding impact of other factors. These factors can potentially affect not only operations performance and the environmental-related options considered, but also the state of the EMS. Of various potential factors, three factors have been identified for inclusion in this study: (1) age of the EMS; (2) size as measured by the resources available to the firm; and (3) the nature of ownership. Each of these three factors will be discussed individually. For each discussion, the factor will be explicated in terms of its relationships to the two sets of dependent variables, and the state of the EMS.

5.1. Age of the EMS

The age of the EMS, or how long it has been in place, should affect corporate performance and how the firm makes use of environmental options. However, the nature of this relationship is difficult to determine "a priori." On one hand, a mature and well-established EMS should encourage management to explore and make use of all the options available to them. Yet, such a system should have also exhausted all of the "low hanging" fruit—those opportunities where management can reduce or eliminate environmental waste streams at little or no real costs. However, these same systems may have been able to resolve those trade-offs inherent to the subsequent opportunities. These trade-offs force management to think in terms of total costs and benefits. Since these subsequent opportunities are far greater in number, they represent a major source of environmental improvements. Finally, as noted by Litsikas (1999), the ISO 14001 certification process is attractive to those firms that lack a formal EMS because it offers management a "blueprint" for developing and implementing an effective EMS. As a result, the attractiveness of certification should be considered because it can influence observed relationships. However, how certification affects these relationships is difficult to determine.

5.2. Resources available to the firm

Corporate resources should play an important role in the environmental options considered by the firm and the state of the EMS for several reasons. First, implementing a formal EMS or certifying that system is a time consuming and potentially expensive undertaking. For example, Litsikas (1999) has noted that it is generally expected that, compared with ISO 9000 certification, the costs of attaining ISO 14001 should be even higher given that this form of certification is more demanding and requires extra paperwork. According to Hormozi (1997), the costs experienced with ISO 9000 are a good indicator of the costs that can be expected with ISO 14001. In addition, even the act of developing a formal EMS may require that the firm have access to a sufficient level of resources. Second, the level of resources available to the firm and its personnel potentially affect the degree to which the various environmental options are used or considered (Dillon and Fisher, 1992). Third, some of the dimensions of corporate performance (dimensions such as reputation) are positively dependent on the level of

resources available to the firm. In general, for this variable, a positive relationship is anticipated (i.e. the higher the level of resources available to the firm, the greater the positive impact on the state of the EMS, the options considered, and the level of performance observed).

5.3. Nature of corporate ownership

This variable focuses on whether the firm is publicly or privately held. On one hand, it can be argued that publicly held firms are least likely to explore environmentally related options or to pursue any actions that affect corporate environmental performance. The rationale for this position can be traced to the work of Walley and Whitehead (1994) who argued for a negative relationship between investments in environmental initiatives and stockholder value. Yet, arguing against this position are the results reported by researchers such as Klassen and McLaughlin (1996), Deutsch (1998), Nielsen (1999), and Delmas (2001). Klassen and McLaughlin (1996) noted that strong environmental management, as indicated by environmental performance awards resulted in significant positive financial performance, as measured by stock market performance. Deutsch (1998) observed that eco-efficient companies reward stockholders with good financial performance. Finally, Nielsen (1999) noted that at least one investment firm, Innovest Strategic Value Advisors, has begun to recommend stocks based on the firm's environmental record. Thus, better environmental performance can improve the value of the firm and attract new stockholders.

In evaluating the data for this study, it is important to note that the major relationships of interest are those that involve the state of the EMS and the impact of the state of the EMS on operations performance and the type of environmental options considered.

6. Research methodology

Data collection for this study was facilitated through the use of a survey instrument. The survey based approach allowed the research team to collect data pertaining to the attitudes of the respondents towards environmental business activities, their plant's environmental management system, and towards voluntary environmental programs such as ISO 14001. The survey was also used to identify factors that influence these attitudes and the respondent's understanding of the effectiveness and efficiency of the plant's environmental management system. The survey instrument, field studies, and general findings can be found in Melnyk et al., 1999. Next, the structure of the survey and the major attributes of the respondents will be briefly summarized.

6.1. Survey design

In order to reduce potential problems with survey items, numerous safeguards were used. First, the specific form we use sets conditions (i.e. strong situation specificity) very high so the ambiguity (which is the usual source of difficulty and confusion) is very low. Specificity of conditions leads to less confusion and higher accuracy of responses in complex assessment questions (Warshaw, 1980; Davis et al., 1989). Second, considerable time was spent in case studies, pilot tests (at two major corporations), and pretesting the survey during personal interviews with executives and experts to ensure that there was little or no ambiguity in the questions and their interpretation. These safeguards help support to the validity of our survey instrument and items.

The survey consisted of five major sections. The first section gathered information about the respondent, their position, professional affiliations (if any), and extent of involvement in various corporate initiatives. The second section focused on the business unit (the basic unit of analysis). This included products manufactured, extent of uncertainty facing the business unit and its personnel, and the status of various initiatives. Section three dealt with the impact of the ISO/QS 9000 certification process on the business unit and its competitive position in the market place. In Section four, the respondent was asked to evaluate a series of questions pertaining to ISO 14001. These questions assessed the respondent's level of knowledge of the ISO 14001 certification process, as well as the factors affecting its implementation and use. The fifth and final section gathered information about the business unit's environmental management system, the effectiveness and efficiency of this system and the types of options used to improve environmental performance.

6.2. The sample and responses

The data used in this study represent the views of a single respondent. Mailing lists of 5000 names each were obtained from three professional associations (National Association of Purchasing Management, American Production and Inventory Control Society and one anonymous group). The lists were checked for duplicate names, with those identified being eliminated. Where possible, the associations were asked to provide names of managers who worked for manufacturers (i.e. in the two-digit Standard Industrial Classification (SIC) code range of 20–39 inclusive). The researchers also worked closely with a major American manufacturer, who provided an additional list of 104 managers at six of their facilities.

Three waves of mailings were sent out, using the modified Dillman (1978) method. The survey was sent out in the fourth quarter of 1997 and responses were received well into 1998. As a result, 1510 usable responses were obtained, for a response rate of 10.35%. The single most serious limitation to direct mail data collection is the relatively low response rate. Mail surveys with response rates over 30% are the exception and not the rule. Large-scale survey response rates are often only about 5–10% (Alreck and Settle, 1995).

When working with survey data, the reliability of the measures is a constant concern. Taking into consideration the low response rate, the research team proceeded with the assumption that the number received would yield a sufficiently large sample to be is representative of American firms, and to have adequate statistical power to test new theoretical models. While the response rates are always lower than researchers would like them to be, the length of this survey discouraged some potential respondents. Examination of the responses found no response bias between the first half of the respondents and the second half of respondents. Information from follow-up phone calls and comments from some participants who did not return the survey all pointed to the 16-page survey instrument taking too much time. Our large sample size and management level position of the respondents (Phillips, 1981) help alleviate some concerns about reliable measure generated from perceptual questions.

6.3. Demographic information

To ensure the survey went only to manufacturing firms, the respondents were asked to list the principal products produced in their plants. These responses (open-ended) were recoded into appropriate SIC codes. From the 40-some SIC codes, 1347 (89.2%) came from the targeted SIC codes, while 110 (7.3%) came from industries out of the target SIC codes, and 53 respondents (3.5%) did not identify their industries. Furthermore, the bulk of respondents (999 respondents or 66.2% of the respondents) were drawn from one of five SIC codes (noted in the brackets):

- Industrial and commercial machinery and computer equipment (35): 316 respondents.
- Transportation equipment (37): 198 respondents.
- Electronic and other electrical equipment and components except computer equipment (36): 179 respondents.
- Fabricated metal products, except machinery and transportation equipment (34): 179 respondents.
- Measuring, analyzing and controlling instruments; photographic, medical and optical goods; watches and clocks (38): 127 respondents.

Based on this information, the analysis focused on firms located in manufacturing industries where environmental business practice are more likely to be found (Handfield et al., 1997). Consequently, it was decided to exclude from further analysis 288 respondents operating in services, printing and publishing, agricultural/forestry. The excluded industries typically do not have an EMS that is given critical consideration and the focus of the research was based on more traditional manufacturing industries. All subsequent statistical analysis was based on data provided by the remaining 1222 respondents.

By limiting the sequent statistical analysis to these 1222 responses, this study recognizes that the industrial setting can significantly influence the relationships that exist between the independent and dependent variables of the theoretical model (as described in the subsequent section). By limiting the responses analyzed to those respondents working in manufacturing settings, this study has tried to introduce a simple control for this effect.

6.4. Operationalizing the research model

To address the research questions posed in this paper, several independent and dependent variables were identified from the survey as being appropriate for addressing the research questions. While the development of EMS research is new, an exploratory approach to the selection of variables was not used. Instead, identification of the variables was based on the literature (Cascio, 1996; Tibor and Feldman, 1996), discussion with practitioners, the experiences of the researchers, and a confirmatory factor analysis with coefficient alphas >0.7. For the independent variables, four were selected and/or developed, where each corresponded to one of the four constructs discussed previously.

6.5. State of the EMS

The first variable is that of the state of the EMS. This variable is based on the responses to the question: "What is the status of ISO 14001 in your company?" The respondent was asked to select a value that best described the status within the company based on a one to seven scale. See Appendix A for all survey items.

The state of the EMS is coded at three levels, where EMS1 is the base case "No Formal EMS in place," EMS2 means the firm has a "Formal EMS in place," and EMS3 consists of those firms having a "Formal certified EMS." The first level, the base case, consists of all respondents who said that ISO 14001 was not applicable, not being considered, is a future consideration, or the plant is assessing its suitability. These firms are considered to have an informal EMS. One assumption of the researchers is that all firms have some sort of system in place for environmental activities and that our efforts to group the respondents reflects the presence of at least an informal system and then different levels of formal systems. The second level consists of those respondents who are planning to implement EMS certification, but who had not yet begun to actively pursue ISO 14001 certification. The final level consisted of respondents who had not only a formal EMS but also one that was either in the process of obtaining certification, or was already ISO 14001 certified.

6.6. Age of the EMS (years)

Each respondent was asked to indicate the number of years that the company EMS was in place. This response, YEARS, was used as a continuous variable to capture the age of the EMS.

6.7. Resource availability

The third variable was SALES. This variable was transformed and consists of four levels, where each level corresponds to a quartile of the reported sales for the company, as reported by the respondent. Using an approach suggested by Hampel et al. (1986), the first quartile represents the lowest amount of resources available, and the fourth quartile represents the highest amount of resources available. Initially this variable was transformed to its natural log to reduce the variance in annual sales while still maintaining a linear relationship to the dependent variable (Cohen and Cohen, 1983). Use of the natural log of this variable later led to no significant relationships in the regression model. Thus, quartiles of the variable are used in the analysis.

6.8. Nature of corporate ownership

This construct was defined in terms of one dichotomous variable (where one indicates "yes"): PUBLIC (publicly traded). The privately owned firm represented the base case. The descriptive information about these four independent variables is summarized in Table 1.

The dependent variables were drawn from two sets of questions. While this study only reports information from respondents in the United States, an 11-point scale was used to facilitate international implementation of the survey (Calantone et al., 1996). The first set of 10 questions asked the respondents to assess the impact of environmental activities on various dimensions of the firm (0—"Strongly Disagree"; 10—"Strongly Agree"). These questions were selected because they asked managers to explicitly identify how they saw EMS affecting dimensions of operations performance such as lead time, cost, quality, and market reputation. The second set of 16 questions asked the respondents to assess the extent to which various environmental options were considered within their plants. For each

Table 1
Independent variables: summary information

Variable	Level	Meaning	Number	Percentage[a]
EMS	1	No formal EMS present	591	50.9
	2	Formal EMS present	475	40.9
	3	Formal certified EMS present	96	8.3
SALES	1	First quartile sales	335	30.9
	2	Second quartile sales	256	23.6
	3	Third quartile sales	254	23.4
	4	Fourth quartile sales	240	22.1
PUBLIC	0	Privately held firm	628	51.4
	1	Publicly held firm	594	48.6
YEARS		Continuous mean = 3.53, S.D. = 5.84	1055	100

[a] Numbers may not equal 100% due to rounding.

of the questions the participants were asked to respond using an 11-point scale (0—"never considered;" 10—"always considered"). Summary information for these 26 performance measures is presented in Table 2.

6.9. Research methodology

To address the research questions presented at the beginning of this paper, the statistical analysis involved a four-step process in which we first checked the normality of the data. Second, we checked to see if the data was consistent with the assumptions of a traditional OLS procedure for regression analysis. The third step involved screened variables for main effects using analyses of variance (ANOVA). The fourth step, built upon on the results of the ANOVA to finally

Table 2
dependent variables: summary information

Variable	Variable label	*N*	Mean	S.D.
Environmental activities within your plant have				
Significantly reduced overall costs	ACTCOST	1142	3.35	2.57
Significantly reduced lead times	ACTLT	1143	2.71	2.28
Significantly improved product quality	ACTQUAL	1144	3.24	2.53
Significantly improved its position in the marketplace	ACTPOS	1140	3.48	2.70
Helped enhance the reputation of your company	ACTREP	1144	4.85	3.09
Helped your company design/develop better products	ACTPRODS	1144	3.60	2.77
Significantly reduced waste within the production process	ACTWPROD	1144	4.73	2.99
Significantly reduced waste within the equipment selection process	ACTWEQIP	1133	4.02	2.79
Had benefits that have definitely outweighed any costs incurred	ACTBENE	1138	4.21	2.83
Improved its chances of successfully selling its products in international markets	ACTINTER	1133	3.73	2.89
To what extent are the following options considered within your company				
Product redesign	OPTPROD	1163	4.99	3.07
Process redesign	OPTPROC	1166	5.95	2.91
Disassembly	OPTDIS	1155	4.03	3.02
Substitution	OPTSUB	1163	6.02	3.05
Reduce	OPTREDUC	1160	5.82	3.03
Recycle	OPTRECYC	1165	5.48	3.19
Rebuild	OPTREBLD	1153	4.80	3.21
Remanufacture	OPTREMAN	1148	4.16	3.12
Consume internally	OPTCONSM	1163	3.66	2.99
Prolong use	OPTPROLN	1154	5.01	3.98
Returnable packaging	OPTREPCK	1162	5.81	3.23
Spread risks	OPTSPRED	1153	4.44	2.89
Create a market for waste products	OPTCREAT	1156	4.24	3.07
Waste segregation	OPTSEG	1161	5.83	3.05
Relocation	OPTRELOC	1153	3.30	2.85
Alliances	OPTALL	1154	4.96	3.05

specify and test the regression models. This procedure enabled the researchers to quantitatively assess the magnitude of the independent variables previously identified. It also permitted the researchers to test if there was a significant difference in performance between having a formal EMS, and having a formal certified EMS. We next discuss each of the steps involved in the analysis.

Step one: The data was tested for normality using both Shapiro–Wilk test (D'Agostino et al., 1990) and the D'Agostino–Pearson tests. Both of these tests are specifically designed to detect departures from normality without requiring that the mean or the variance of the hypothesized normal distribution be specified in advance. The tests are more specialized to normality testing and tend to be more powerful in this role than the Kolmogorov–Smirnov test. Both tests indicated that the data was non-normal and pathologically skewed for most variables at the 0.05 level of significance. This precluded any assumption of normality from this point on in our analysis.

Step two: After assessing normality of the data, the next step in our analysis determined whether the data is consistent with the conventional assumptions of regression analysis. Traditionally, Ordinary Least Squares (OLS) assumes that the data is homoscedastic and normally distributed. When these assumptions are violated, the reliability of the results generated by the OLS becomes suspect (Kennedy, 1998). When faced by data that fails one of these requirements, the user can turn to one of two basic approaches, transforming the data, or using a regression procedure that is adept to departures of normality.

We explored and actually tested the suitability of various transformations. We applied Box's Ladder of Power procedure. This procedure evaluates the extent to which any one of nine commonly recommended transformations (cube, square, raw, square root, log, reciprocal root, reciprocal, reciprocal square, and reciprocal cube) could generate a new distribution that was normally distributed (as evaluated using a χ^2-test for normality). None of the transformations were successful for the set of dependent variables tested.

Next, we re-examined the distributions in light of attempted transformation. Indications obtained from Q–Q and P–P analyses revealed data characterized by "fat" centers and yet having a number of extreme outliers. Additionally, the distributions generally tended to be right skewed. For these reasons, we used robust regression due to the violation of normality and presence of outliers.

Step three: We next determined the nature of the relationships presented in the study. Primarily, this step determined the extent to which higher order interactions were present. Since the independent variables are categorical in nature and the dependent variables can be treated as interval, a series of univariate full-factorial ANOVAs were developed. With a full factorial design, we could evaluate the extent to which significant first order (and higher) effects were present. This knowledge would be then used in determining the structural form of the subsequent regression equations.

Step four: Based on the information from the previous two steps, robust regression analysis was carried out using the guidelines and procedures set forth by Berk (1990). This procedure was implemented using STATA Version 6.0 (StataCorp, 1999). This procedure is well suited to working with data sets characterized by non-normality. Specifically, it begins by estimating the regression equation, calculating Cook's D and then excluding any observations for which $D > 1$. Thereafter, it works iteratively: it first carries out a regression, calculates the weights based on absolute residuals, and regresses again using those weights. Weights are derived from one of two weight functions: Huber weights and biweights. Both weights are used jointly because of limitations encountered when using each alone. For example, Huber weights have problems dealing with severe outliers. In contrast, biweights occasionally fail to converge or generate multiple solutions. For all statistical tests, an α of 0.05 was used to assess statistical significance.

7. Discussion of results

After assessing non-normality and departures from some of the assumptions of regression analysis, 26 full factorial univariate ANOVAs were run. Since they are essentially preparatory, the results of these runs are not reported in detail. The performance variable results are summarized in Table 3, while environmental options results summarized in Appendix B. In all cases, the models were significant (as denoted by the F-statistic) and, with the exception of two instances (both observed for the options-oriented models), the

Table 3
Full factorial ANOVA: summary results of performance variables

Performance variables	*F*-statistic	Significance	Number of significant higher order effects
ACTCOST	6.19	0.0000*	0
ACTLT	3.77	0.0000*	0
ACTQUAL	5.60	0.0000*	0
ACTPOS	7.45	0.0000*	0
ACTREP	14.30	0.0000*	0
ACTPRODS	5.94	0.0000*	0
ACTWPROD	8.62	0.0000*	0
ACTWEQIP	6.84	0.0000*	0
ACTBENE	8.56	0.0000*	0
ACTINTER	8.95	0.0000*	0

* $P < 0.05$.

higher order interactions were *not* significant. With no theoretical support for including the two interactions, it was decided to include only main effects in the resulting regression equations for the fourth stage of analysis. To test for omitted variable bias of the model, all regressions were tested using the Ramsey regression specification test for omitted variables (Ramsey, 1969; Ramsey and Schmidt, 1976). The regression specification error identified no problems with the models used in this study. The use of a main effects regression model simplifies the interpretation of the resulting findings, especially as they pertain to the β weights, since these can now be viewed as capturing the incremental effects of the each independent variable on the resulting dependent variables.

For each of the regression equations, the independent variables were coded as dummy variables. The intercept was treated as the base case. This case consisted of the following conditions:

- no formal EMS;
- first quartile sales;
- privately held.

The result is that the independent variables were represented by six dummy variables, one continuous variable, as well as the intercept. The resulting regression models involve

$$\begin{aligned} &26\,\text{individual DVs} \\ &\quad = \text{intercept} + \text{EMS2} + \text{EMS3} + \text{SALES2} \\ &\qquad + \text{SALES3} + \text{SALES4} + \text{PUBLIC} \\ &\qquad + \text{YEARS} + \text{error} \end{aligned}$$

An additional variable was used to test for a significant difference between having a formal EMS and a formal certified EMS. This variable EMS2–EMS3 is also included in the results in Table 4. The results of the regression analyses involving performance are summarized in Table 4. The results of the regression analysis for environmental options are summarized in Appendix C.

We will first examine and discuss the results of the corporate performance variables. A summary of the significant findings by independent variables for these two categories of dependent variables is presented in Table 5.

7.1. Corporate performance

First, it is important to note that for each of the 10 performance variables, the overall model is significant. Second, for the four sets of independent variables, the pattern of behavior and influence was generally consistent across performance variables. Differences between the two stages of a formal EMS (EMS2–EMS3) were significant for 8 of the 10 options.

Basically, we see the corporate performance findings support Hypothesis 1 indicating the impact of environmental activities on corporate performance is strongly affected by the presence of a formal EMS and strongly influenced by the presence of a formal, certified EMS. The significant variables include ACTCOST, ACTLT, ACTPOS, ACTREP, ACTPRODS, ACTBENE, and ACTINTER. The impact of the other factors, when taken as a whole and compared with the EMS state variables, are not as strong. In examining these findings, we focus on explaining the results pertaining to the impact of the EMS.

One explanation of the results is that what we observed the specialized impact of the EMS. The resource based view of the firm (Wernerfeldt, 1984; Russo and Fouts, 1997) supports the idea that the EMS provides the firm with specialized information for critical functions. These systems and functions are necessary for the firm and its personnel to reduce pollution and to improve overall performance. Without a formal EMS, the firm may have no other method of obtaining this same type of information. Alternatively, it could be argued that what we observing is greater awareness of the environmental efforts taking place in the firm and greater awareness of the impact of these

Table 4
Regression results: performance variables

Factors	ACTCOST	ACTLT	ACTQUAL	ACTPOS	ACTREP	ACTPRODS	ACTWPROD	ACTWEQIP	ACTBENE	ACTINTER
EMS2	1.21 (0.000)*	0.77 (0.000)*	1.07 (0.000)*	1.15 (0.000)*	2.09 (0.000)*	0.76 (0.004)*	1.76 (0.000)*	1.27 (0.000)*	1.54 (0.000)*	1.26 (0.000)*
EMS3	2.44 (0.000)*	1.55 (0.000)*	1.61 (0.000)*	2.53 (0.000)	3.85 (0.000)*	1.58 (0.000)*	2.96 (0.000)*	1.87 (0.000)*	2.62 (0.000)*	3.42 (0.000)*
SALES2	0.03 (0.909)	−0.09 (0.642)	0.04 (0.866)	0.18 (0.438)	−0.07 (0.800)	0.06 (0.565)	−0.11 (0.687)	0.30 (0.243)	−0.11 (0.674)	0.17 (0.501)
SALES3	−0.09 (0.692)	0.01 (0.967)	0.31 (0.179)	0.26 (0.286)	0.46 (0.092)	0.26 (0.312)	0.20 (0.459)	0.37 (0.157)	0.21 (0.414)	0.59 (0.024)*
SALES4	−0.12 (0.622)	−0.01 (0.954)	0.21 (0.376)	0.54 (0.032)*	0.68 (0.016)*	0.79 (0.003)*	0.24 (0.406)	0.42 (0.127)	0.19 (0.481)	0.71 (0.008)*
PUBLIC	0.39 (0.027)*	0.24 (0.128)	0.36 (0.039)*	0.03 (0.119)	0.46 (0.025)*	0.51 (0.008)*	0.52 (0.012)*	0.50 (0.012)*	0.36 (0.068)	0.55 (0.005)*
YEARS	0.13 (0.476)	0.01 (0.430)	0.03 (0.189)	0.34 (0.058)	0.05 (0.057)	0.06 (0.011)*	0.03 (0.189)	0.05 (0.042)*	0.05 (0.026)*	0.01 (0.697)
Constant	2.44 (0.000)*	2.07 (0.000)*	2.30 (0.000)*	2.26 (0.000)*	3.14 (0.000)	2.35 (0.000)*	3.36 (0.000)*	2.68 (0.000)*	2.97 (0.000)*	2.30 (0.000)*
N	910	910	911	908	910	910	911	902	906	903
F	16.21	9.10	13.45	19.58	39.96 15.92	24.07	17.20	23.94	23.49	
P > *F*	0.000*	0.000*	0.000*	0.000*	0.000* 0.000*	0.000*	0.000*	0.000*	0.000*	
EMS2–EMS3 (*F*-statistic)	12.68 (0.0000)*	6.34 (0.011)*	2.44 (0.1187)	14.74 (0.0001)*	19.12 (0.000)*	4.73 (0.0298)*	8.69 (0.0033)*	2.26 (0.1252)	7.93 (0.0050)*	31.67 (0.000)*

* $P < 0.05$.

Table 5
Summary of variables with significant findings

Independent variables	Performance variables	Environmental-related option variables
Number of variables	10	16
Overall model	10	16
EMS2	10	16
EMS3	10	16
SALES2	0	4
SALES3	1	4
SALES4	4	8
PUBLIC	7	6
YEARS	3	10
EMS2–EMS3	8	6

efforts on not only pollution reduction/elimination but also on the other areas of operations performance. This explanation would emphasize the role of the EMS as a "clearinghouse" of information about the environmental efforts of the firm. The presence of the EMS promotes awareness and communication of environmental activities.

Hypotheses 1 posits significant differences between the lack of a formal EMS, presence of a formal system, and the presence of a formal certified EMS. The results support the hypothesis and also leave researchers with interesting questions as to why there are significant differences between the different types of systems. The improvement generated by the presence of a certified formal EMS, as compared to a formal, but uncertified, EMS, can be explained in several ways. The first is that the act of a plant-wide certification, helps to involve many people in different positions and functions. In the process of involving these people, they become aware of the environmental activities of their firm. Alternatively, it could be argued that what we are observing is the impact of external review and verification—a critical requirement of ISO 14001 certification. That is, before the EMS can be ISO 14001-certified, it must be evaluated by an impartial third party. It could be that evaluation motivates the real improvements. Finally, it could be argued that we are observing benefits generated from focusing on underlying processes. Ideally, ISO 14001 certification forces the people involved to examine the various processes and not just the outputs of the firm. By focusing on these processes and ideally altering them, the firm gains real and long-term improvements not only in the decreased level of pollution generated but also by increasing operations performance. This improvement in performance is due to the elimination of waste discovered when examining the various processes. Further research is required to test the posited relationships.

Overall, resource availability and age of the EMS exercised the least amount of influence on performance. Within resource availability, SALES2 and SALES3 had almost no impact with only one performance variable, ACTINTER (improved chances of selling in international markets) having a significant relationship with the second quartile of sales. Resource availability was only found to have an impact at the very high levels of sales in the fourth quartile (SALES4). Even then, a significant effect (P-value of 0.01 or better) was noted only for 4 of the 10 performance variables. Its average influence, as indicated by this variables coefficient was also limited averaging 0.68.

Publicly held firms had some impact on performance. Here we see significant coefficients noted for 7 of the 10 performance variables. Even when significant, the relative impact, as denoted by the average of the significant coefficients for PUBLIC, was limited (being 0.47).

However, it was the state of the EMS that was found to have the most significance and largest impact. For all 10 performance variables, both EMS2 (a formal but uncertified EMS) and EMS3 (a formal and certified EMS) were found to have a significant impact on performance. Furthermore, this impact was relatively large when compared to other coefficients (on average, the coefficient assigned to EMS2 was 1.29 while the average coefficient assigned to EMS3 was 2.44). Finally, the difference in performance between EMS2 and EMS3 was significant in 8 of the 10 variables. This indicated that having a formal EMS, while significant, was not enough. In most cases, the firm benefited from having a formal EMS that was also certified.

7.2. Environmental option variables

For the option variables, the overall model was significant for every environmentally related dependent variable. Furthermore, EMS2 and EMS3 were again found to have a positive effect and significant

impact on the use of all 16 options. Additionally, the differences between the two stages of a formal EMS (EMS2–EMS3) was significant in the use of only 6 of the 16 options.

The impact of resources was slightly more pronounced. For 4 of the 16 options, both SALES2 and SALES3 were found to have a significant and positive impact on the level of the options used. In contrast, the impact of resources was highest at the SALES4 level, with this variable having a significant and positive relationship with eight of the options used. Public ownership was found to have a significant relationship with six of the 16 options.

In reviewing the findings for environmental options, attention is devoted to looking at the impact of the state of the EMS and the Age of the EMS. What these findings argue for is that the impact of certification is limited when it comes to the level of options used. While certification can affect the performance of the firm, certification is limited as to the extent with which firms use certain options. In these cases where there is a significant difference between the certified formal EMS and uncertified EMS (EMS2–EMS3), the options involved are those that can be best described as being reactive. The significant variables include OPTSEG, OPTCREAT, OPTSPREAD, OPTREPCK, OPTREBUILD, and OPTREMAN. Options such as OPTSEG (segment waste streams), and OPTCREAT (creating markets for waste streams) OPTRMAN (remanufacturing) and OPTREBUILD (rebuilding products) are options where the level of waste created is not changed through proactive process or design changes. Rather, there is an attempt to manage these waste streams so as to reduce their end-of-life impact. This would seem to argue that the process of becoming certified makes plant-level personnel more aware of the opportunities available for the more effective and efficient disposal of waste. One possible reason for the focus on waste is that the process of studying the various waste processes required by the ISO 14001 standard. The ISO 14001 certification process creates a greater awareness of the opportunities for better disposal of waste streams. The reasons for the focus on waste options warrants further investigation by future studies. Given the results of the regression analysis, Hypothesis 2 is supported for only six of the environmental option variables. Otherwise, all environmental options are significant and do not demonstrate a strong difference between options pursued with a informal ESM and a formal EMS.

In contrast, we find a more persistent impact for the age of the EMS (years). YEARS has a significant (P-value of 0.01 or better) influence on the level of the options used for 10 of the 16 options. Some additional support for Hypotheses 2 is found when examining the difference in options for firms with formal systems and firms without systems. One way of interpreting this result is to argue that when it comes to the use of environmentally related options, it is experience (as represented by YEARS) that has an impact. As firms become more experienced with EMS and the various options, management is more likely to draw on these options to improve environmental performance.

8. Directions for future research

While this study has addressed an assessment of the incremental impact of not only formalizing the EMS but also attaining ISO 14001 certification, it has also uncovered several areas in which future research is needed. The first area involves undertaking a more detailed assessment of the impact of industry on the relationship between EMS and performance at the operational and corporate levels. Industry is used as a surrogate to capture a number of effects, including degree of regulation (past or current), environmental opportunities, past experience with EMS, degree of visibility of environmental problems, and opportunities for environmental improvements within the supply chain. Consequently, a more detailed analysis of this industry variable is needed so that a better understanding of its effects (and the nature of its effects) can be developed.

A second area of interest for future research involves the analysis of the relationships highlighted in the study using alternative statistical procedures. The relationships described in this paper can be evaluated using not only robust regression but also path models. Such an analysis might provide alternative and potentially rich insights into the new EMS relationships demonstrated in this study.

Third, there is a need to replicate this study. The data was collected over a period of time when ISO

14001 certification was a relatively new concept to many American managers. This period could be viewed as the introductory stage. ISO 14001 is now becoming more prevalent. More sites worldwide are being certified (Corbett and Kirsch, 2001). Consequently, it would be useful to evaluate what changes, if any, have taken place in the relationships studied in this paper. Such an analysis would require another sample similar to the one described in this study.

Finally, there are a number of question involving the EMS that must resolved. Given that the formal EMS does play a critical role in the firm's attempts to improve environmental and operations performance, what are the minimum components of such a system? Do the ISO 14001 environmental standards fully describe all of the elements that should be present in such a system? These and other similar questions are left for future researchers to address.

9. Concluding comments

This study began by exploring a question that pertained to the importance and impact of the formal EMS and certification of this EMS. The EMS is important because it is not only at the heart of the ISO 14001 certification process, but also integrated within operations management. Implicit in this certification is the assumption that the EMS is critical to the firm's attempts to reduce or elimination the waste and pollution created by the fabrication, use, and disposal of a product.

This study has evaluated the impact of environmental systems on self-reported measures of corporate performance, and the environmental options a firm pursues. A limitation of the study is that environmental information is extremely hard to obtain. With this in mind, self-reported measures of performance from plant-level experts is only way in which information is obtained about EMS attributes, environmental options, and impacts of these types of systems on operations management and performance. Based on the information from plant-level experts within the United States, the results demonstrate that these types of environmental systems are critical to the management and reduction of waste. The results of our research show many significant relationships between the presence of a formal EMS or a certified EMS and improved performance such as reduced costs, improved quality, the reduction of waste in the design and equipment selection process, and reduction of lead times.

Basically, a formal EMS does play a role in improving overall performance; it also affects the frequency with which various environmentally related options are used. Furthermore, certification of these systems does have a significant incremental impact on performance and on the reactive options the plants involved in the study considered. This study demonstrates that certification, as embodied within the ISO 14001 environmental standards, brings with it real benefits.

Acknowledgements

This research is supported in part by the National Science Foundation Division of Design, Manufacture, and Industrial Innovation (ECM Initiative), Grant no. DMI-9528759. Additional support was provided by the Center for Advanced Purchasing Studies (CAPS) of the National Association for Purchasing Management (NAPM) and the Education and Research Foundation of the American Production and Inventory Control Society (APICS). The authors wish to acknowledge with gratitude the assistance in the data collected and used in this paper rendered by Frank L. Montabon (Iowa State University), and Sime Curkovic (Western Michigan University).

Appendix A

1. Total annual sales of your "company": ($000) _____.

2. Is your company: ☐ publicly traded ☐ privately owned

State of the EMS survey item:

Please Read Carefully
For each program listed down the left side, please place an "X" in the cell which best describes its status in your company (only one (1) "X" per row please).

WHAT IS THE STATUS OF THE FOLLOWING DEVELOPMENTS IN YOUR COMPANY?

	Not Applicable	Not Being Considered	Future Consideration	Assessing Suitability	Planning to Implement	Currently Implementing	Successfully Implemented
ISO 14000							

(The whole table is not shown in this appendix)

3. If your company does have a formal environmental management system in place, how long has that system been in place? _____ years.

4. Environmental activities within your firm have:	**Strongly Disagree** ↓									**Strongly Agree** ↓
Significantly reduced overall costs	0	1	2	3	4	5	6	7	8	9	10
Significantly reduced leadtimes	0	1	2	3	4	5	6	7	8	9	10
Significantly improved product quality	0	1	2	3	4	5	6	7	8	9	10
Significantly improved its position in the marketplace	0	1	2	3	4	5	6	7	8	9	10
Helped enhance the reputation of your company	0	1	2	3	4	5	6	7	8	9	10
Helped your company design/develop better products	0	1	2	3	4	5	6	7	8	9	10
Significantly reduced waste within the production process	0	1	2	3	4	5	6	7	8	9	10
Significantly reduced waste within the equipment selection process	0	1	2	3	4	5	6	7	8	9	10
Had benefits that have definitely outweighed any costs incurred	0	1	2	3	4	5	6	7	8	9	10
Improved its chances of successfully selling its products in international markets	0	1	2	3	4	5	6	7	8	9	10

Appendix A (*Continued*)

5. To what extent are the following options considered within your company:	**Never Considered**										**Always Considered**
Product redesign: redesigning the product to eliminate any potential environmental problems (manufacturing or recycling)	0	1	2	3	4	5	6	7	8	9	10
Process redesign: redesigning the process to eliminate any potential environmental problems	0	1	2	3	4	5	6	7	8	9	10
Disassembly: redesigning the product or process so as to simplify disassembly and disposal at the end of the product's useful life	0	1	2	3	4	5	6	7	8	9	10
Substitution: replacing a material which can cause environmental problems with another material which is not problematic	0	1	2	3	4	5	6	7	8	9	10
Reduce: reducing the level of material and/or components (which are contributing to environmental problems) within products	0	1	2	3	4	5	6	7	8	9	10
Recycling: making more use of recycled components or making a product which is more easily/readily recycled.....	0	1	2	3	4	5	6	7	8	9	10
Rebuilding: rebuilding a product where some of the parts or components are recovered while others are replaced.....	0	1	2	3	4	5	6	7	8	9	10
Remanufacturing: like rebuilding, except that none of the parts are reduced to raw materials.....	0	1	2	3	4	5	6	7	8	9	10
Consume Internally: consuming waste internally (e.g., wood pallets used in shipping or product storage used to generate electrical power in a co-generation facility) .....…….....	0	1	2	3	4	5	6	7	8	9	10
Prolonging Use: reducing environmental problems by increasing the overall life of the product (e.g., engines which now last longer before having to be replaced or rebuilt) .....……	0	1	2	3	4	5	6	7	8	9	10
Returnable Packaging: Using packaging and pallets which can be returned after they are finished being used.....	0	1	2	3	4	5	6	7	8	9	10
Spreading Risks: shifting responsibilities for environmental problems to a third party or expert better able to deal with issues	0	1	2	3	4	5	6	7	8	9	10
Creating a market for waste products: treating waste as an input to another product which can be made and sold at a profit.....	0	1	2	3	4	5	6	7	8	9	10
Waste Segregation: an intermediate action in which waste streams are separated out into their individual components before being recycled, reused or consumed internally.....….	0	1	2	3	4	5	6	7	8	9	10
Relocation: changing the location of a process or plant to take advantage of more favorable environmental regulations and conditions	0	1	2	3	4	5	6	7	8	9	10
Alliances: working with either suppliers or customers to address environmental problems and/or issues	0	1	2	3	4	5	6	7	8	9	10

Appendix B

Full factorial ANOVAS—summary results: environmental options

OPTPROD	6.27	0.0000*	0
OPTPROC	11.43	0.0000*	0
OPTDIS	5.55	0.0000*	1 (EMSSTATE × SALES × PUBLIC ($F = 10.94$, significance at 0.01))
OPTSUB	8.99	0.0000*	0
OPTREDUC	10.52	0.0000*	0
OPTRECYC	6.84	0.0000*	0
OPTREBLD	4.32	0.0000*	0
OPTREMAN	3.86	0.0000*	0
OPTCONSM	4.94	0.0000*	1 (EMSSTATE × SALES ($F = 2.52$, significance at 0.02))
OPTPROLN	3.65	0.0000*	0
OPTREPCK	5.00	0.0000*	0
OPTSPRED	3.01	0.0000*	0
OPTCREAT	5.91	0.0000*	0
OPTSEG	7.50	0.0000*	0
OPTRELOC	5.85	0.0000*	0
OPTALL	10.14	0.0000*	0
Total significant higher-order interactions			2

* $P < 0.05$.

Appendix C

Regression results: environmentally-related option variables (part I)

Factors	OPTPROD	OPTPROC	OPTDIS	OPTSUB	OPTREDUC	OPTRECYC	OPTREBLD	OPTREMAN
EMS2	1.03 (0.001)*	2.08 (0.000)*	1.01 (0.001)*	1.75 (0.000)*	1.75 (0.000)*	1.25 (0.000)*	0.93 (0.004)*	1.16 (0.000)*
EMS3	1.51 (0.001)*	2.37 (0.000)*	1.59 (0.000)*	2.11 (0.000)*	2.04 (0.000)*	2.10 (0.000)*	2.27 (0.000)*	2.54 (0.000)*
SALES2	0.39 (0.172)	0.77 (0.002)*	0.37 (0.182)	0.29 (0.278)	0.43 (0.109)	0.34 (0.244)	0.55 (0.066)	0.16 (0.590)
SALES3	0.62 (0.036)*	0.57 (0.029)*	0.52 (0.069)	0.34 (0.219)	0.35 (0.200)	0.58 (0.055)	0.17 (0.586)	−0.04 (0.894)
SALES4	0.67 (0.028)*	0.56 (0.039)*	0.61 (0.040)*	0.34 (0.031)*	0.37 (0.195)	0.89 (0.004)*	0.15 (0.648)	0.28 (0.365)
PUBLIC	0.52 (0.017)*	0.55 (0.005)*	0.29 (0.169)	0.60 (0.004)*	0.60 (0.004)*	0.17 (0.451)	0.31 (0.185)	0.15 (0.512)
YEARS	0.09 (0.001)*	0.05 (0.031)*	0.08 (0.002)*	0.05 (0.035)*	0.08 (0.001)*	0.08 (0.004)*	0.06 (0.038)*	0.01 (0.807)
Constant	3.47 (0.000)*	4.14 (0.000)*	2.70 (0.000)	4.52 (0.000)*	4.24 (0.00)*	4.14 (0.000)*	3.74 (0.000)*	3.31 (0.000)*
N	920	921	913	920	917	920	912	908
F	17.35	32.63	15.43	24.65	28.12	17.91	10.43	8.78
P > *F*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
EMS2–EMS3	1.17	0.53	1.86	0.73	0.50	3.56	8.35	9.49
F-statistic	0.2787	0.4663	0.1730	0.3926	0.4817	0.0596	0.0039*	0.0021*

* $P < 0.05$.

Appendix D

Regression results: environmentally-related option variables (part II)

Factors	OPTCONSM	OPTPROLN	OPTREPCK	OPTSPRED	OPTCREAT	OPTSEG	OPTRELOC	OPTALL
EMS2	1.39 (0.000)*	1.21 (0.000)*	0.96 (0.003)*	1.04 (0.000)*	1.41 (0.000)*	1.55 (0.000)*	0.60 (0.028)*	1.85 (0.000)*
EMS3	1.82 (0.000)*	1.21 (0.011)*	2.29 (0.000)*	2.07 (0.000)*	2.35 (0.000)*	2.58 (0.000)*	1.00 (0.017)*	2.44 (0.000)*
SALES2	0.57 (0.038)*	0.06 (0.833)	−0.34 (0.264)	0.01 (0.977)	0.01 (0.607)*	0.55 (0.047)*	−0.13 (0.606)	0.71 (0.009)*
SALES3	0.38 (0.188)	0.05 (0.869)	0.56 (0.075)	−0.25 (0.372)	0.66 (0.025)*	0.54 (0.062)	0.33 (0.214)	0.68 (0.016)*
SALES4	0.98 (0.001)*	0.41 (0.190)	0.38 (0.238)	−0.02 (0.937)	0.69 (0.024)*	0.21 (0.485)	0.23 (0.405)	0.76 (0.009)*
PUBLIC	0.17 (0.440)	0.04 (0.859)	0.35 (0.134)	0.14 (0.506)	0.42 (0.059)	0.20 (0.353)	0.62 (0.002)*	0.46 (0.029)*
YEARS	0.01 (0.804)	0.04 (0.193)	0.34 (0.165)	0.01 (0.796)	0.01 (0.607)	0.06 (0.018)*	0.10 (0.000)*	0.05 (0.032)*
Constant	2.36 (0.000)*	4.12 (0.000)*	4.96 (0.000)*	3.88 (0.000)*	2.93 (0.000)*	4.51 (0.000)*	2.12 (0.000)*	3.12 (0.000)*
N	918	913	920	912	916	920	915	914
F	11.65	8.22	11.37	6.97	14.69	19.34	15.77	26.86
P > *F*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
EMS2–EMS3	1.05	0.00	8.09	5.85	4.70	5.71	1.03	2.04
F-statistic	0.3063	0.9936	0.0045*	0.0157*	0.0305*	0.0171*	0.3108	0.1540

* $P < 0.05$.

References

Alreck, P.L., Settle, R.B., 1995. The Survey Research Handbook, Second ed. Irwin (Richard D.), Homewood.

Anonymous, 1999. Ford and GM demand ISO 14001 compliance. Quality 38 (13), 12–16.

Berk, R.A., 1990. A primer on robust regression. In: Fox, J., Long, J.S. (Eds.), Modern Methods of Data Analysis. Sage, Newbury Park, CA, pp. 292–324.

Block, M.R., 1999. What there saying about standards: truly global standard. Quality Progress 32 (7), 28.

Bonifant, B., Ratcliff, I., 1994. Competitive implications of environmental regulations in the pulp and paper industry. In: Management Institute for the Environment and Business. World Resource Institute, Washington, DC.

Brewer, J., Hunter, A., 1989. Multimethod Research: A Synthesis of Styles. Sage, Newbury Park, CA.

BSI, 1996. Implementation of ISO 14001: specifications with guidance for use. British Standards Institute, London.

Caillibot, P., 1999. What there saying about standards: integration of ISO 14000 and 9000. Quality Progress 32 (7), 29.

Calantone, R., Schmidt, J., Song, M., 1996. Controllable factors of new product success: a cross-national comparison. Marketing Science 15 (4), 341–358.

Cascio, J., 1996. The ISO 14001 Handbook. Fairfax, CEEM Information Systems, Virginia.

Cohen J., Cohen, P., 1983. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Lawrence Erlbaum, New Jersey.

Corbett, C.J., Kirsch, D.A., 2001. International dispersion of ISO 14000 certifications. Production and Operations Management 10 (3), 327–342.

Curkovic, S., Melnyk, S.A., Handfield, R.B., Calantone, R.J., 2000. Investigating the linkage between total quality management and environmentally responsible manufacturing. IEEE Transactions on Engineering Management 47 (4), 444–446.

D'Agostino, R.B., Balanger, A., D'Agostino Jr., R.B., 1990. A suggestion for a using powerful and informative tests of normality. The American Statistician 44 (4), 316–321.

Davis, F., Bagozzi, R., Warshaw, P., 1989. User acceptance of computer technology. Management Science 35 (8), 982–1003.

Delmas, M., 2001. Stakeholders and competitive advantage: the case for ISO 14001. Production and Operations Management 10 (3), 343–358.

Deutsch, C.H., 1998. For Wall Street, Increasing Evidence that Green Begets Green, Section 3. New York Times, 19 July, p. 7.

Dillman, D.A., 1978. Mail and Telephone Surveys: The Total Design Method. New York, Wiley.

Dillon, P.S., Fisher, K., 1992. Environmental Management in Corporations: Methods and Motivations. Center for Environmental Management, Tufts University, Tufts.

Global Environmental Management Initiative (GEMI), 1996. ISO 14001 Environmental Management System Self-Assessment Checklist. GEMI, Washington, DC.

Hampel, F.R., Ronchetti, E.M., Rousseeuw, P.J., Stahel, W.A., 1986. Robust Statistics: The Approach Based on Influence Functions. Wiley, New York.

Handfield, R., Walton, S., Seegers, L., Melnyk, S., 1997. Green value chain practices in the furniture industry. Journal of Operations Management. 12 (5), 38–53.

Hormozi, A.M., 1997. ISO 14001: the next focus in standardization. S.A.M. Advanced Management Journal 62 (3), 32–41.

ISO World, 2000. World-wide figures on ISO 14001 certification are available from the web site: http://www.ecology.or.jp/isoworld/english/analy14k.htm.

ISO, 1999. The ISO Survey of ISO 9000 and ISO 14000 Certificates. The Eighth cycle: up to and Including 1998, ISO Central Secretariat: http://www.iso.ch/.

Jaffee, A.B., Peterson, S.R., Portney, P.R., Stavins, R.N., 1993. Environmental Regulations and the Competitiveness of US Industry. Economics Resource Group, Cambridge, MA.

Kennedy, P., 1998. A Guide to Econometrics, 4th ed. MIT Press, Cambridge, MA.

Klassen, R.D., McLaughlin, C.P., 1996. The impact of environmental management on firm performance. Management Science 42 (8), 1199–1214.

Litsikas, M., 1999. US perspective varies on ISO 14001. Quality 36 (12), 28–33.

Melnyk, S.A., Calantone, R., Handfield, R., Tummala, R.L., 1999. ISO 14001: Assessing its Impact on Corporate Effectiveness and Efficiency. Center for Advanced Purchasing Studies, National Association of Purchasing Management, Tempe, AZ.

Miles, M.P., Russel, G.P., 1997. ISO 14000 total quality environmental management: the integration of environmental marketing, total quality management, and corporate environmental policy. Journal of Quality Management 2 (1), 151–168.

Montabon, F., Melnyk, S., Sroufe, R., Calantone, R., 2000. ISO 14001: assessing its perceived impact on corporate and purchasing performance. The Journal of Supply Chain Management 36 (2), 4–16.

Nielsen, K., 1999. Green management may lift stock value. Chemical Week 161 (26), 73–76.

Pava, M., Krausz, J., 1996. The association between corporate social responsibility and financial performance: the paradox of social cost. Journal of Business Ethics 15, 321–375.

Phillips, L.W., 1981. Assessing measurement error in key informant reports: a methodological note on organizational analysis in marketing. Journal of Marketing Research 18 (4), 395–415.

Porter, M.E., 1991. America's greening strategy. Scientific American 264 (4), 168.

Porter, M.E., Van der Linde, C., 1995a. Green and Competitive—Ending the Statement. Harvard Business Review, September–October, pp. 120–134.

Porter, M.E., Van der Linde, C., 1995b. Toward a new concept of the environment-competitive relationship. Journal of Economic Perspectives 9 (4), 97–118.

Ramsey, J.B., 1969. Tests for specification errors in classical linear least squares regression analysis. Journal of the Royal Statistical Society, Series B 31, 350–371.

Ramsey, J.B., Schmidt, P., 1976. Some further results on the use of OLS and BLUS residuals in specification error tests. Journal of the American Statistical Association 71, 389–390.

Reid, D.R., 1999. What they're saying about standards: integrated management standard. Quality Progress 32 (7), 32.

Rothenberg, S., Pil, F.K., Maxwell, J., 2001. Lean, green, and the quest for superior performance. Production and Operations Management 10 (3), 228–243.

Russo, M.V., Fouts, P.A., 1997. A resource based perspective on corporate environmental performance and profitability. Academy of Management Journal 40 (3), 534–559.

Sayre, D., 1996. Inside ISO 14001: the competitive advantage of environmental management. St. Lucie Press, Delray, Beach, FL.

Sroufe, R., 2000. Environmental Management Systems: Implications for Operations Management and Firm Performance. Ph.D. Dissertation. Michigan State University, Michigan.

Sroufe, R., Curkovic, S., Montabon, F., 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.

StataCorp, 1999. Stata Statistical Software, vol. 3. Stata Corporation, College Station, TX.

Tibor, T., Feldman, I., 1996. ISO 14001: A Guide to the New Environmental Management Standards. Irwin, Burr Ridge, IL.

Vickery, S.K., Dröge, C., Markland, R.E., 1993. Production competence and business strategy: do they affect business performance? Decision Sciences 24 (2), 435–455.

Walley, N., Whitehead, B., 1994. Its not easy being green. Harvard Business Review 72 (3), 46–52.

Warshaw, P., 1980. Predicting purchase and other behaviors from general and contextually specific intentions. Journal of Marketing Research 17 (3), 26.

Wernerfeldt, B., 1984. A resource-based view of the firm. Strategic Management Journal 5, 171–180.

Wood, D.J., 1991. Corporate social performance revisited. Academy of Management Review 16 (4), 691–718.