ENVIRONMENTAL MANAGEMENT SYSTEMS: IMPLICATIONS FOR OPERATIONS MANAGEMENT AND FIRM PERFORMANCE

by

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ABSTRACT

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To date, definitional ambiguity surrounds Environmental Management Systems (EMS). This research defines the construct of an EMS and tests several posited relationships to operations management and firm performance. With research in the area of environmental business being relatively new, this dissertation develops a new and strong theoretical foundation for the EMS construct.

The objectives of the research are to define an EMS and test the direct and indirect effects between the status of an EMS and firm performance. These objectives will be accomplished through the exploration of the following research questions.

1. Is there an EMS construct?
2. What is the impact of EMS on operations performance?

Working from the existing theory of industrial organizations, the resource based view of the firm and corporate social performance, the research presented in this dissertation posits and tests several theoretical linkages between the EMS construct, uncertainty, environmental practices, and firm performance. In addition to investigating theoretical linkages between EMSs and firm performance, the expected scholarly contribution includes building theory by answering the following subordinate, but critical questions:

1. What are the sources of uncertainty for the development of an integrated EMS?

2. What is the relationship between EMSs and environmental practices a firm pursues? For the context of this research, the environmental practices will be limited to design, manufacturing, and waste practices. The mediated relationships between EMSs and perceived firm performance demonstrate interesting indirect relationships that have not yet been explored.
3. Is an integrated EMS an example of resource productivity?
4. How do factors such as end sales (% of sales to end consumer), amount of export, European exports, ownership, and resources (size, sales, etc.) impact the "State of the EMS"?

A multi method approach operationalizes and tests EMS relationships with uncertainty, environmental practices, and firm performance. The primary approach to testing relationships is that of structural equations modeling using survey data. The survey is complimented with follow up interviews and field visits with managers at eight firms.

The results of this research are of interest to both academic colleagues and managers in the field in that it eliminates confusion about what exactly is an EMS, and demonstrates both direct and indirect relationships to operations performance such as lower costs, improved quality and flexibility. The results presented in this dissertation demonstrate the development of a new theory, which explains how EMS, as a new operations management capability, leverages firm performance. The results suggest that efforts should be coordinated to take advantage of the benefits of EMSs, while also objectively assessing the environmental options available to a firm.

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CHAPTER 1

OVERVIEW OF THE RESEARCH

1.1 INTRODUCTION

Chapter One is a review of the dissertation. The purpose of this dissertation is to provide empirical insights to existing Environmental Management System (EMS) practices, which will be useful to industrial professionals. These insights will provide managers with a new and much needed source of interesting and useful information about EMS development and the impact of EMSs on firm performance. Academic colleagues should be interested in this dissertation because it contains an isomorphic model based on industry practices that is empirically tested and contributes to theory development.

While working with EMSs in the past, two questions triggered my interest in environmental practices and information systems. (1) What is an EMS? (2) How is an EMS linked to operations management performance? Based on these two questions, a dissertation and the ideas within the dissertation have taken shape over the last three and a half years. The remainder of this section will provide a roadmap to the subsequent sections of Chapter One specifically, and the dissertation in general.

Chapter One is comprised of several sections that lay out the approach taken to generate and evaluate the ideas and research questions surrounding EMSs. Section 1.2 highlights the need to conduct EMS research and describes a paradox that has evolved in the field of environmental research. Additionally, this section touches upon some of the more important articles which are reviewed in detail in Chapter Two. Section 1.3 discusses the objectives of the research in the form of primary and secondary research questions and also discusses a conceptual model. Section 1.4 reviews the overall research methods while specifically talking about data collection and the approach used for testing the conceptual model. Section 1.5 discusses the limitations of the dissertation while Section 1.6 defines the contributions of the dissertation to the existing body of knowledge. Section 1.7 details the road map for the rest of the chapters in the dissertation. Finally, Section 1.8 is a chapter summary.

1.2 The Need for EMS Research

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

The difficulty for managers is compounded by a paradox that is evolving in the literature. This burgeoning paradox involves a dearth definition of EMSs and the growing importance for this type of system. One of the only definitions of an EMS is: "the organizational structure, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental management" (ISO 14001 1996). The definition of an EMS has never been operationalized or empirically tested and its normative properties are very vague. Thus, definitional ambiguity has left practitioners with only a few frameworks and insights, while researchers struggle with measuring and operationalizing of the EMS construct. Here is the evolving paradox of EMSs. Consequently, environmental practices are gaining the attention of managers and researchers, very little good research exists as to what the defining attributes of an EMS really are, or how EMSs impact firms.

This dissertation aims to resolve the EMS paradox by (1) developing a more comprehensive definition of an EMS, (2) examining current environmental business practices, and (3) gaining an understanding of the factors influencing EMSs. A new definition of an EMS resulting from this research involves:

> 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 from the definition of an EMS, researchers can look at the relationship of the EMS and firm performance. The study of this relationship will fill a large gap in the literature. The dissertation and EMS research can provide insight to managers regarding current practices and better information to aid decisions concerning EMS projects, resource allocation, and impacts on firm performance. Improved firm performance is but one facet of a manager's responsibilities.

Without an understanding of current practices, capabilities, and the impact of EMSs on firm performance, many poor decisions will be made due to the lack of accurate information. It appears researchers are missing an opportunity to extend the "capabilities" of the firm to include EMSs and environmental practices along with technology, information, flexibility, structure, and capacity.

Managers are now required to develop and produce goods and services that are not only better (higher quality), have shorter lead times, are less expensive (i.e., lower cost to produce) and more flexible, but that also are more environmentally responsible (Melnyk, Sroufe, Montabon, and Calantone 1999). But, an understanding of how managers are to accomplish all of these requirements is not supported by empirical research. Instead, the field is a long way from understanding environmental requirements and the role of EMSs in the firm.

To understand how the role of EMSs meet the new requirement of environmental responsibility, researchers can learn from other existing theories and practices. One theory that closely parallels the environmental movement is the quality movement. It took several years, even decades for Total Quality Management (TQM) to become integrated in most firms globally. Much the same as the quality movement, the environmental movement is slowly becoming recognized as a capability of the firm to impact the bottom line (Klassen McLaughlan 1996).

Much like the challenges of TQM, the environmental challenge to firms involves perfecting manufacturing processes while also considering environmental performance. Therefore, the approach taken in this research is to see pollution (a waste product that consumes resources for its generation and disposal) as equivalent to a high rate of defects, and by definition as the result of faulty processes (Kleiner 1991).

Comparable to the TQM movement, one way to eliminate waste or "pollution" is to understand conversion processes and eliminate non-value-added practices. The use of

EMSs is recognized by many as the means to better understand and control conversion processes (Tibor and Feldman 1996). Thus, EMSs can meet new environmental objectives and influence firm behavior by improving accountability, and creating a store of corporate knowledge while supporting decision-making processes. Much the same as the early stages of TQM development, and despite the recognized need for integrated systems and shared environmental information, the capabilities of EMS still go empirically untested.

1.2.1 Impacts of EMSs

One approach to further developing EMS capabilities is to research and analyze the direct and indirect impacts on the firm. Direct mechanisms for improving the capabilities of a firm may impact increased productivity and material yield, while indirect methods impact the firm through practices such as quality conformance. Other direct mechanisms may include the specialized environmental information captured, tracked and disseminated by an EMS that can impact procurement, maintenance, and manufacturing productivity. Thus, EMSs can both directly and indirectly impact the capabilities of the firm.

Examples of the impact of an EMS can be found in flexibility, quality, and lead time. EMSs can improve flexibility if a firm simultaneously improves output across several products (Swamidass and Newell 1987; Gerwin 1993). This, flexibility may be reached through the reduction of environmental waste and resources associated with manufacturing processes. Improved quality may be achieved through the reduction of waste and a better understanding and control of conversion process (Garvin 1987). Additionally, an EMS can reduce lead times and lower costs through providing environmental information on suppliers and through the reduction of waste (Porter 1980; Prahalad and Hamel 1991; Collins and Montgomery 1995).

According to Tibor and Feldman (1996) utilizing EMSs is one method of directly impacting conversion processes. If this is true, then several opportunities may exist for an EMS to enhance the operations management capabilities of a firm by providing specialized environmental information. For example, with the control of conversion processes come the opportunities to improve the design of products (Sroufe, Curkovic, Montabon, and Melnyk 2000), and reduce waste (Womack and Jones 1994).

There are many additional reasons why EMSs should impact the firm. Dun (1997) discusses the ability of an EMS to impact the firm through reduced stock risk perceived by investors. Firms with an EMS have the ability to reduce multiplicity/duplication or reporting requirements (Litskas 1999). There is also the potential impact of the certification for an EMS becoming a de facto requirement for doing business (Tibor and Feldman 1996). An EMS can enhance pollution prevention by providing information to aid in the reduction of hazardous wastes going to landfills or discharged into the environment (Tibor and Feldman 1996; Greer 1997). EMSs may also be able to provide information for reporting purposes that help to enhance the reputation of the firm. Thus, marketing improved environmental performance becomes a motivation for the development of an EMS. Finally, EMSs can help the firm achieve environmental excellence (Melnyk, Tummala, Calantone, and Goodman 1996).

When looking at the benefits of an EMS such as the improved capabilities mentioned above, it would be expected that there would be more interest from researchers in the development, implementation, and practices involving these types of systems than there currently is. Current practices such as the Ford Motor Company making public statements that all automotive manufacturing operations worldwide will have third party certified EMSs by the year 2000 reveals some insight from this multinational company (Ford Motor Company 1999). Additionally, Ford and General Motors (GM) are requiring suppliers to have EMS certification (Daniels 2000). Ford and GM's actions imply that EMSs has benefits that exceed their costs, but this may be considered an "extreme, or proactive" position by some. Other firms such as 3M, Dow Chemical Corporation, and Herman Miller believe their current EMSs are more advanced than international standards and are taking a "wait and see" approach to EMS certification (Krut and Drummond 1997). Still smaller firms and industries outside the chemical and automotive industry may be the real laggards, or "reactive" in development of efficient and effective EMS. The question still goes unanswered, why isn't there greater acceptance of EMSs?

Using the above extreme positions, as the boundaries, there is the need to explore what is happening with the majority of firms. Those firms found near the proactive end of the spectrum, include Innovators and Early Adopters of environmental initiatives. These firms tend to be in the minority (Sroufe, Curkovic, Montabon, and Melnyk 1999). Firms found near a reactive boundary will only address environmental problems after they have been created. This approach does not address the actual problem, but instead treats the symptoms of the problem ex post facto. This is a very risky position for a firm since compliance with environmental regulations is not an issue until the firm is in a state of non-compliance. More often, firms are found somewhere between the extremes, i.e., large Original Equipment Manufacturers claiming to have advanced EMSs, or small reactive firms without a formal EMS.

The challenge for many managers is to determine where to position the firm in terms of EMS development. This determination can be made easier by an analysis of the associated costs which will help firms determine if it is better to seek compliance as a minimal approach, find some middle ground, or be recognized as a leader in the development of an EMS. Due to a lack of research and agreement among those who have spoken out on the issues of EMSs, conflicting information about the environmental practices is available to managers, thus complicating the decision process.

In summary, there is a recognized need for firms with important environmental challenges to better understand how the capabilities of an EMS can help meet the changing needs of the firm. Critical steps toward a better understanding come through research that explores EMS development and the impact of this system on the capabilities of the firm. Given the dearth of solid empirical research, important questions to be asked and answered in this research field are: How can these systems have improve firm performance, or meet the changing needs of the firm? Is the presence of an EMS enough? If not, what are the factors that shape effective EMS development and implementation?

1. 2. 2 Empirical Endeavors

Conflicting paradigms have evolved in the literature. The conflict is between the supporters of "win-win" environmental proponents such as Porter (1991a); and Van Der Linde (1995a, 1995b) and the proponents of the "lose-lose" environmental scenario such as Jaffe, Peterson, Portney, and Stavins (1993; 1994); Walley and Whitehead (1994).

What is at issue is the conflict over environmental business practices impacting more than just environmental performance. The issues of environmental business practices have gone round for round in academic journals with no real resolution to the idea that investments in better environmental processes and systems will impact more than just a firm's environmental performance. Given the current state of research in this field, it would appear that environmental performance and business performance may only be linked by happenstance.

Through the lens of the "win-win" environmental advocates, the conflict between environmental protection and economic competitiveness is said to be a false dichotomy (Porter 1991b). Porter and Van Der Linde (1995a) refer to environmental "win-win" situations where *resource productivity* leads to better firm performance. Walley and Whitehead (1994) instead choose to show environmental "lose-lose" situations anecdotally. Additionally, there has been a lack of good empirical resolution to the conflicting paradigms to date. Thus, the constructs and relationships encountered when dealing with environmental practices still remain poorly operationalized. In addition, the overall relationships and structures of models and theory are generally lacking. Further, there exists a poor understanding of how certain decisions are arrived at, how actions are implemented, and how these decisions and actions impact the competitiveness of the firm.

Such unresolved conflicts spring from and are coupled with the research deficiencies in the environmental field reveal:

- Conflicting paradigms: It has been argued that being environmental practices ultimately makes a company more efficient and more competitive (Royston 1980; Porter 1991b; Bonifant 1994a, 1994b; Bonifant and Ratcliff 1994; Porter and Van Der Linde 1995a; Van Der Linde 1995a, 1995b, 1995c). However there are many reported cases of environmental investments that have resulted in negative returns (Jaffe, Peterson, Portney, and Stavins 1993, 1994; Walley and Whitehead 1994).

- Normative and anecdotal approaches: Managers need frameworks or guidelines that they can use to better understand what EMS is and its components. However, a great deal of the information surrounding environmental issues is very vague and either legally based or derived from anecdotal stories and case studies (Piet, 1994; Danesi 1996; Porter and Van Der Linde 1995a; Walley and Whitehead 1994)
- Environmental Management Systems practices: Managers have difficulty assessing the impact of EMSs and EMS programs because of a lack of appropriate measures. Both researchers and managers still need a more detailed definition of EMSs and development of EMS practices. While there exists a vague definition of an EMS and many hypothesized relationships, no one has yet to operationalized this construct, or empirically tested EMS relationships. From the literature there are many opinions and knowledge of EMSs, yet proof of the relationships to other constructs is lacking. In order for EMSs to be given serious consideration by a firm, a process is required for evaluating what constitutes an EMS.
- Perceived impact of EMSs on the firm: Investing in an EMS will be given serious consideration by a firm if the system appropriately includes environmental costs and savings for investment option (Sarkis and Rasheed 1995; Epstein 1996). Again, the literature yields no detailed discussion of how an EMS currently captures and disseminates information.

This contradictory and ambiguous situation presents an opportunity for good empirical research into EMSs. There appears to be a clear need for empirical investigation of the issues associated with EMSs and a framework for the motivations and impacts of EMS integration. There is also a need for a theoretical foundation for EMS, which can be used to resolve the evolving EMS paradox and explain why firms would want to invest in EMSs.

The aim of this dissertation is to resolve conflicts in the literature and develop a theoretical foundation for EMSs. The research is concerned with developing a sound EMS by focusing on identifying this construct, developing scales for this construct, and empirically validating the scales. As discussed in Section 1.1, the current definition of EMS is very vague. The ISO 14001 definition is not based on empirical research and leaves the components of the definition open to criticism. Basically, the EMS literature suffers from a lack of specific criteria involving systematic scale development, content validity, and empirical validation. Hence, the existing definition falls short of overall generalizability of results. Only when these three criteria for theory building are met will empirical studies be undertaken which involve hypothesis generation and theory testing.

This creates a tremendous opportunity for groundbreaking research in EMSs which involves understanding how different types of uncertainty impact a firm's EMS status, identifying the attributes of an EMS, identifying the types of environmental practices a firm will consider, and understanding the impacts on non-environmental performance such as new product design, enhanced firm reputation, quality, cost, flexibility and leadtime. Additional insight is gained through exploring the impact of variables such as the size of the firm, resources available, and market incentives for an EMS.

This dissertation is oriented towards meeting the challenge of operationalizing constructs and developing and empirically testing relationships and frameworks. These activities take place within the setting of identifying and testing the extent to which a manufacturing plant has an integrated EMS. Specifically, this dissertation focuses on the identification of valid and reliable measures of an EMS. Second, this dissertation deals with the relationships between uncertainty, the impact of the EMS on environmental practices the firm will pursue, and the relationship to perceived firm performance. Finally, the dissertation will attempt to answer questions as to the impact of the size of the firm, sales, and amount of exported products on the status of an EMS.

1.3 Primary Research Questions

The objectives of the research are to define an EMS and test the direct and indirect effects between the status of an EMS and firm performance. These objectives will be accomplished through the exploration of the following research questions.

1. Is there an EMS construct?
2. What is the impact of EMS on operations performance?

This research will identify and discuss what it means for a firm to have an EMS and to what extent the firm has developed and integrated this system into business practices. Additionally, the answers to these questions will help explain the relationship between the EMS, the environmental practices a firm may choose (design, manufacturing, and waste) and the impact of the system and these practices on perceived firm performance.

The motivation and development for the primary research questions are guided by the recommendations of Davis (1971), Kuhn (1963) and Platt (1964) who noted that research should be driven by four major considerations. The first is that the research should be feasible. The second is that the results should be useful. The results of this research will impact management by addressing their major concerns. Third, research should be linked to theory. In proposing and testing the research questions, the underlying theory is explicated and refined. The results should guide the elimination of unnecessary aspects of prior models, introduce new dimensions to consider and reframe other aspects with lasting value. Finally, the research should be "interesting" (Davis 1971). That is, the research should capture the audience's attention and take notice of the results because they provide the person with unique and "interesting" insights into the events being studied.

1.3.1 Secondary Research Questions

While EMS theory is far from being well developed, the research can establish a valid and reliable framework for the study of EMSs. In addition to investigating theoretical linkages between EMSs and firm performance, the expected scholarly contribution includes building theory by answering the following subordinate, but critical questions:

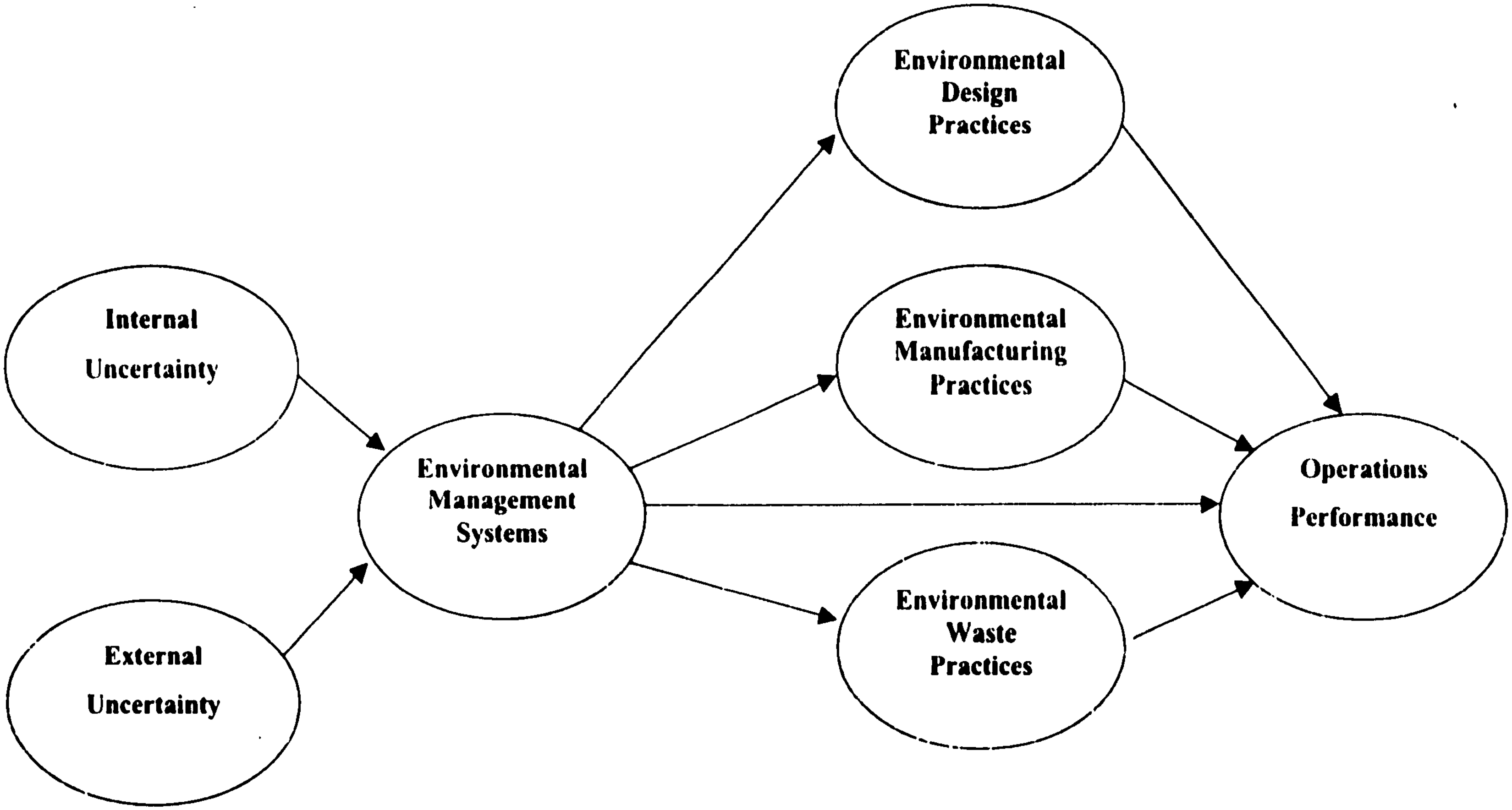
1. What are the sources of uncertainty for the development of an integrated EMS?
2. What is the relationship between EMSs and environmental practices a firm pursues? (For the context of this research, the environmental practices will be limited to design, manufacturing, and waste practices. The mediated relationships between EMSs and perceived firm performance demonstrate interesting indirect relationships that have not yet been explored.)
3. Is an integrated EMS an example of resource productivity? (If the answer is yes, then it lends support to Porter and Van Der Linde (1995a).)
4. How do factors such as end sales (% of sales to end consumer), amount of export, European exports, ownership, and resources (size, sales, etc.) impact the "State of the EMS"? (This approach resembles the chasm model and separate firms into Innovators, Early Adopters, Early Majority, Late Majority, and Laggards (Moore 1991).)

The dissertation will contribute to theory building by identifying constructs, developing scales for measuring the constructs, and empirically validating the scales. The advancement of EMS research depends on measurement. This measurement is critical to link theoretical concepts to empirical indicants.

1.3.2 Research Model

The conceptual model is shown in Figure 1.1. Justification for the model's relationships are given below with a more comprehensive explanation provided in Chapters two and three.

FIGURE 1.1 CONCEPTUAL MODEL



Theory may be viewed as a system of constructs and variables in which the constructs are related to each other by propositions and the variables are related to each other by hypotheses (Bacharach 1989). A good theory is a clear explanation of how and why specific relationships lead to specific events. This section of chapter one will define the constructs, and discuss the underlying measures.

Since EMSs are new, the constructs are not well developed in the literature and many manifest variables will be used to examine the necessary validity and reliability in measuring some of the constructs. This approach fits well with Hunt's (1991) approach to theory development. In this approach, research starts with propositions and constructs that are derived from our knowledge of the field and certain assumptions. Next, these assumptions are arranged into a hypothesized model. Finally, the model is analyzed and attempts are made to deduce generalizations. The following explanation of the theoretical model is derived from the literature, interviews with managers, research projects with the Michigan State University Manufacturing Research Center, National Science Foundation research projects, research colleagues, and this researcher's knowledge of the field.

This model can be segmented into four general areas: uncertainty and firm effects, status of the EMS, environmental practices, and firm performance. The first half of the model attempts to explain the relationships between sources of internal and external uncertainty and the status of the EMS. This portion of the model generally borrows from the paradigm of industrial organization, and specifically from the Structure – Conduct - Performance (SCP) literature (Porter 1979, 1981, 1991a; Miller 1987; Rumelt 1991). The SCP posits that industry structure will dictate the actions necessary for firms within an industry which will in turn effect the performance of the firm. The relationships between the sources of uncertainty and the development of an EMS can explain a firm's motivation for pursuing EMSs and under what conditions this may happen. Also within the first half of the model are the relationships between firm effects and EMS development. This aspect of the model will attempt to show relationships between firm size, industry, resource availability, and sales on the status of the EMS. These relationships are important to an understanding of what types of firms will be involved in EMS development and integration.

The second half of the model explores the paths between the different types of environmental practices (e.g., design, waste, and manufacturing) a firm will explore and the relationships of these practices with improved firm performance. It is posited from the literature that an EMS will positively impact the way products are designed and manufactured (Cozata, and Mintu-Wimstatt 1995). Additionally, the presence of an EMS should provide specialized information that is critical to the reduction of waste for products or processes (Tibor and Feldman 1996). Borrowing from the resource based view of the firm (Wernerfelt 1984; Russo and Fouts 1997; Starik and Rands 1995; Klassen and Whybark 2000b), and corporate social performance theories (Wood 1991; Pava and Krausz 1996), there is a posited positive impact on firm performance. In turn, the presence of the EMS and the utilization of different design, manufacturing and waste practices should also impact firm performance (Tibor and Feldman 1996). The second half of the model explores the impact of mediating relationships, e.g., environmental practices, on perceived firm performance, testing both indirect and direct relationships between EMSs and firm performance.

Such a holistic model will help explain and predict why firms will want to invest in an EMS. So , too, it will develop the attributes of an EMS, and lead to a better understanding of the factors that influence the status of an EMS, the types of environmental practices a firm pursues, and finally the relationship to improved operations management performance.

1.4 Research Methodology

1.4.1 Data Collection

The data collection has been done in two-phases. The first phase involves model development using the literature, field studies and interviews with managers. The second phase involves the implementation of a large scale survey designed to validate scales for measuring the underlying constructs. This multimethod approach should exploit the strengths and weaknesses of both field studies and surveys while reducing the problems associated with both. The survey will allow the researcher to record the attitudes of the respondents towards EMSs, environmentally responsible manufacturing, and ISO 14000. Additionally, it can be used to identify factors that influence these attitudes and the perceived effectiveness and efficiency of the plant EMS.

The first phase of the research methods was designed to ensure content validity through the development of the survey and pretesting the instrument with managers and other researchers. The instrument was then adjusted according to their feedback before implementation in the Fall of 1997.

The survey consisted of 232 items grouped into five major sections. The first section gathered information about the respondent, their position, professional affiliations (if any), and extent of involvement in various initiatives (such as Just-in-Time or Lead

Time Reduction programs). The second section focused on the business unit (the basic unit of analysis), paying particular attention to details such as annual sales, and industry sector. This included the product manufactured, extent of uncertainty facing the business unit and its personnel, and the status of various types of initiatives (e.g., Enterprise Resources Planning, Cross Functional Teams and ISO/QS 9000). The third section dealt with the perceived 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 14000. 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 practices used to improve environmental performance.

Multiple industries were chosen for implementation of the instrument to show what is happening within several industries rather than being limited to environmental business practices of isolated extreme cases such as those already highlighted in previous literature (Walley and Whitehead 1994; Clarke, Stavins, Greeno, and Bavaria et.al. 1994; Clarke, Cairncross, Walley, Whitehead, et. al. 1994; Porter and Van Der Linde 1995a). Three professional associations provided mailing lists of 5,000 names each. The constituency of each of the associations was different enough that only a handful of names were found on more than one list. In total, a mailing list of 14,584 names were used, of which 1,453 usable responses were received (a response rate of 9.9%).

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 to 10 percent (Alreck and Settle 1995). Reliability of the data depends on the size of the sample obtained, and not the number of surveys sent, so the research team made an estimate of the response rate and mailed enough questionnaires to yield the approximate number of responses required. Knowing the survey instrument was quite lengthy, a very large number of surveys were sent using the modified Dillman (1978) approach. Assuming a 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 power to test complex structural equation models.

One way of determining the extent to which the sample is representative is to evaluate the industrial settings from which the respondents were drawn. The respondents were asked to list the principal products produced in their plants. These open-ended responses were then coded in conformance with the Standard Industrial Classification (SIC) codes by an external panel. For the purposes of this coding, a two-digit SIC code was used.

From the 40-some SIC codes, the bulk of respondents were drawn from one of five SIC codes:

- Industrial & Commercial Machinery & Computer Equipment (35): 316 respondents.
- Transportation Equipment (37): 198 respondents.
- Electronic & Other Electrical Equipment & Components Except Computer Equipment (36): 179 respondents.
- Fabricated Metal Products, Except Machinery & Transportation Equipment (34): 179 respondents.
- Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks (38): 127 respondents.

To an extent, it can be argued that the concentration of the respondents from these five sectors is consistent with the manufacturing activities within the United States (U.S.

Census Bureau 1997; Economic Indicators 1999; Stoneman 1999). In addition, these five industries should be interested in ERM-oriented activities within their firms. Other indicators of the diversity from the survey data include the median number of Full Time Equivalent Employees, a proxy for plant size (400), percentage of export sales (19.7%), percent of sales to the European Community (9.7%), and the average percentage of sales going to the end customer (24.6%). Furthermore, 729 plants (48.3%) were publicly owned, 250 (16.6%) were foreign-owned, and 54 plants (3.6%) were joint ventures.

1.4.2 Testing the Model

With data collection and data entry completed in the summer of 1998, attention turns to the primary method of analysis, Structural Equation Modeling (SEM). SEM is similar to path analysis in that it provides parameter estimates of the direct and indirect links between observed variables. An important distinction is that SEM explains covariation in the data. SEM requires formal specification of the model to be tested and requires the researcher to think and hypothesize relationships a priori. SEM is similar to regression techniques in that there is a quantification of relationships between dependent and independent variables. Using SEM is a more comprehensive and flexible approach to research design and data analysis than any other single statistical model. 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 data in the research, EQS (Bentler 1989) will be used. This software is generally identical to LISREL (Jöreskog and Sörbom 1989), but uses simpler terminology and notation (Brown 1986). The goodness-of-fit test is carried out using chi-square and other tests, which are available in EQS. The parameter estimates are derived from using maximum likelihood estimation (MLE) or Elliptical Reweighted Least Squares (ERLS) estimation methods. This research will use both MLE and ERLS estimation methods to test the hypothesized model.

Using a confirmatory factor-analytic approach, it is possible to test the hypothesized relationships between the manifest variable and the latent variable constructs. While there were over two hundred variables to choose from, an exploratory factor analysis (EFA) will not be performed. Instead, the researcher's knowledge of the field and previous literature was used to create the hypothesized model (see Figure 1.1) consisting of 7 constructs, and 92 measures (see Appendix 1.). EQS will be used for both the CFA and SEM results presented in this dissertation. Structural equation modeling will show the more complex multivariate relationships between all of the latent and manifest variables simultaneously.

Additional analysis will be done through regression analysis and univariate analysis of variance to test the relationships between the firm effect variables and the EMS system.

1.5 Scope of the Dissertation

The structural equation model is not all-inclusive. All relevant factors have not been identified and all linkages not fully developed. The dissertation primarily develops the associated traits of EMS theory and explores the relationships between the EMSs and perceived firm performance. The approach to the research in this dissertation will use qualitative and quantitative methods to collect and analyze data from a large-scale survey. Analysis of the data will test the relationships between different motivations for obtaining an EMS, the extent that the EMS is integrated and cross-functional, the types of environmental practices firms consider, and the relationship to perceived firm performance.

The effectiveness and efficiency of an EMS will depend on several factors including: ISO 14000, information system implementation issues, the type of firm ownership, types of regulations the industry must comply with, corporate culture and so on. It is beyond the scope of the dissertation to address all of these factors. Thus, this dissertation will not look at ISO 14000 certification or implementation issues surrounding ISO 14000, secondary sources of financial performance data, Suppliers and supplier assessment, Life Cycle Analysis (LCA), or only the extreme cases of an EMS.

1.6 Contribution of the Research

The research is aimed at satisfying academic and practitioner interests in environmental business practices and specifically EMSs. From an academic perspective, the goal is to develop and assess a rationally consistent theory of EMSs. Operationalizing the EMS construct will bridge gaps in the literature while simultaneously building theory. The multimethod approach of qualitative and quantitative approaches to the data collection and analysis lends itself well to the development of valid and reliable scales for the latent variable of an EMS. Theory building will be supported through the explanatory and predictive powers of the model. Additionally, theory building will also discuss the implications of the integration of information systems such as Enterprise Resource Planning, Materials Requirements Planning, New Product Design, Accounting, and EMSs.

The results will be of interest to managers faced with decisions regarding EMSs and environmental practices. In situations where environmental projects may be thought of as a "cost of doing business," the results of the research may provide evidence of benefits that exceed the costs, and help practitioners understand what the attributes of a well-developed EMS consist of. The research will also help to resolve the conflict between competing paradigms which drive environmental manufacturing practices. The model and analysis, if statistically significant, will demonstrate the link of environmental practices to more than just environmental performance. The research will also demonstrate the link to performance measures such as reputation, improved position in the marketplace, cost, quality, lead-time, and flexibility.

1.7 Structure of the Dissertation

Chapter two will be a comprehensive review of the literature. The main bodies of literature involve management's structure-conduct-performance literature, EMSs, ERM, ISO 14000, the resource based view of the firm, corporate social performance, and design for environment. Based on the literature review in chapter two, chapter three will discuss the theoretical model and constructs while covering pre-research and research design issues. Chapter four will present the analysis of the data. Chapter five will discuss the results, conclusions, and implications. Finally, there are the references and appendices.

1.8 Chapter Summary

Chapter one highlights the fact that practitioners have very complex decisions to make when it comes to developing, implementing, and measuring successful EMSs. Unfortunately, there are conflicting paradigms that add to decision complexity and confuse both researchers and practitioners. Thus, there is a need to resolve the conflict and develop a theory of EMSs.

EMSs are loosely defined in the literature and this existing definition has not been operationalized. The research will explain the attributes of a well-developed EMS. While the relationship between environmental performance and EMSs seems logical, researchers do not understand the relationship between EMSs and firm performance. Based on the literature and the researcher's knowledge, a conceptual model is posited. The model highlights the linkages between sources of uncertainty, the stage of EMS development, the environmental practices a firm may consider, and both indirect and direct relationships between EMSs and firm performance.

A subsample of the original 1453 respondents to an EMS survey is used to test the model and hypothesized relationships. Data analysis involves confirmatory factor analysis and structural equation modeling. A multimethod approach is used for research design and analysis. The research is based on the literature, field studies, interviews with managers, projects with the Michigan State University Manufacturing Research Consortium, and a research grant from the National Science Foundation.

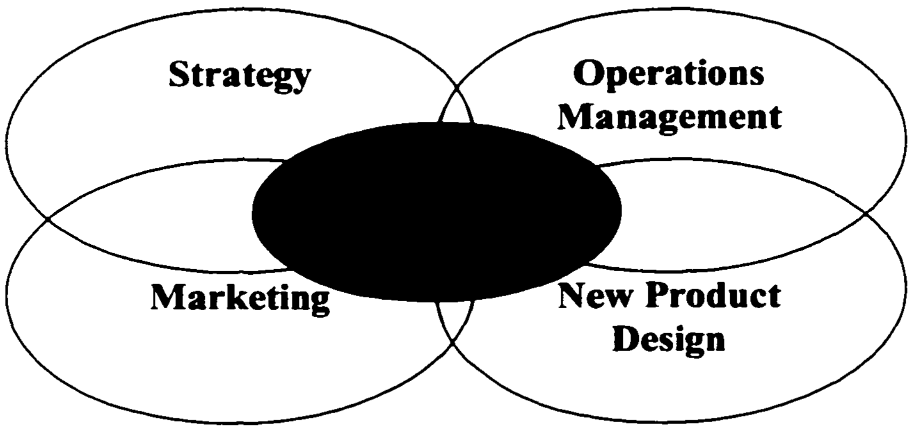
CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

Environmental Management Systems (EMSs) involve a broad field of literature and a contradiction. The broad field includes functional areas such as strategy, operations management, marketing, purchasing, finance, logistics, and so on. The contradiction is found in the sense that empirical literature is lacking, yet there is a large amount of knowledge and normative work on EMSs. Therefore, it becomes difficult for a literature review to be "comprehensive" while also being directional and purposeful. This literature review is not comprehensive in all fields of study, and instead focuses on critical articles within selected fields (see Figure 2.1).

Figure 2.1 Functions Impacting EMS



While focusing on select fields, the literature review includes information from the following topical areas that are found in the conceptual model (see Figure 1.1):

- Importance of environmental issues
- Sources of uncertainty for the firm
- Firm Effect

- Environmentally Responsible Manufacturing (ERM)
- The International Organization of Standards (ISO) 14000 Environmental Management Standards
- Environmental management systems
- Environmental practices a firm may consider (Design, manufacturing, waste reduction, and pollution prevention)
- Firm performance.

Citations used for this literature review are, in part, derived from an Environmetnally Responsible Manufacturing (ERM) database containing over 12,000 citations at Michigan State University's Department of Marketing and Supply Chain Management. The focus of the ERM database is to create a repository for research on ERM issues published in refereed journals, conference proceedings, practitioner publications such as Businessweek or Newsweek, books, and monographs. Because environmental issues did not receive much attention prior to the 1970s, the database was restricted to articles published since this time. This database helped to ensure a comprehensive examination of the body of literature as it pertained to the EMS construct specifically, and environmental research in general. The intention was to exhaustively review the literature.

The literature review begins with Section 2.2 and the growing importance of environmental issues and the impact of these issues on different types of uncertainty a firm will face. Section 2.3 explores the conflicting paradigms in the business literature, while Sections 2.4 and 2.5 discuss sources of uncertainty and potential firm effects. Next, Sections 2.6 and 2.7 discuss the topics of ERM and ISO 14000 and help to explain the purpose and reasons a firm would pursue EMS development. Section 2.8 develops a new definition of an EMS. Then, Section 2.9 explores the environmental practices plants consider and shows their integration into EMS and the ERM practices of a firm. Finally, the last section discusses the potential of EMS to impact firm performance.

2.2 Growing Importance of Environmental Issues

When asking managers about the importance of the environment, researchers find that it is more than some will admit and less than some would hope. This section of the literature review highlights some of the key reasons why environmental issues are important. There are generally four reasons why firms should take notice of environmental issues. These reasons include, increased regulations, first mover advantages, governmental pressures, and stakeholder perceptions of the firm.

The first key reason for the importance of environmental issues relates to the external forces on the firm such as regulations. The proponents of more environmental regulation for business have gained support from Porter (1991a), who briefly discussed the question of whether strict environmental standards make American industry less competitive in international markets? Porter claims the viewed conflict between environmental protection and economic competitiveness is a false dichotomy. Strict environmental regulations do not inevitably hinder competitive advantage against foreign competition; indeed they often enhance it (Rondinelli, Berry and Vastag, 1997). Due to regulations, some multinational corporations (MNC) that invest in emerging market economies are often accused of seeking pollution heavens and exploiting local conditions to gain quick profits at the expense of the poor and vulnerable (Korten, 1996).

The second key reason for the importance of environmental issues involves first mover advantages. It has been claimed that firms involved in proactive environmental programs can lead the way into environmental stewardship, and new regulatory requirements (Rondinelli, Berry and Vastag 1997). While first mover advantages may help to establish new regulatory requirements, there are also several cases of enhanced financial performance (Makower 1994). Considering the cost/benefit tradeoffs associated with being the standard setter and being a follower, there are times when government or the competition seek "best-in-practice" environmental companies as a benchmark. Firms that are laggards in adopting new standards and conforming to existing regulations will be reactive and spend valuable resources in order to stay abreast of the active development of their competitors, and new governmental regulations. Borrowing from the resource based view of the firm (Wernerfelt 1984), those firms who are exceeding regulatory compliance, and have proactive investments in previous environmental initiatives may help defend the firm against new compliance issues, costs, and competitors.

Additional evidence of the growing importance of environmental business practices can be seen in the adoption of environmental practices by governments such as North American, Indonesia, and China (Wheeler and Afsah, 1996; Graff 1997; Anonymous 1997). Due in part to governments recognizing the importance of environmental business practices, corporations now must evaluate the appropriate corporate environmental policies for their plants and supply chain partners while being consistent with new international standards (Rondinelli and Vastag, 1996).

Aside from looming environmental legislation, first mover advantages, and potential governmental pressures, firms still have to handle the delicate issues of special interest groups, stakeholders, customers, and communities around the facility. Thus, the perception of the firm becomes a key reason for the increased importance of environmental issues. The 1998 United Nations Climate Conference on discussing the controlling of global warming, and specifically reduction of carbon dioxide and other greenhouse gases to below 1990 levels has brought growing attention to the environmental impacts of businesses in many countries.

Recognizing the growing importance of environmental issues, there should be a growing need for empirical research. The environmental issues confronting businesses are wrought with opinion and charged with emotion. One way to avoid the emotion of environmental issues is through objective research that can help explain and predict business activities and help managers make better decisions. A review of the status of environmental research in business is necessary to understand what information is available to help managers and researchers alike.

2.3 A Review of the Business Literature "Conflicting Paradigms"

The growing importance of environmental issues that have been tested empirically is relatively small compared to the amount of effort spent on normative and anecdotal literature. While the environmental movement may have its origins in the early 1970s, the articles that helped to shape and develop research in the environmental business field really started in the early 1990s. Kleiner (1991) raises the question of "what does it mean to be green?" While no distinct definition of *greenness* is given, the author does raise some interesting questions concerning what environmental products should be brought to market, how much disclosure of environmental information is enough, is compliance enough, and how can companies reduce waste at the source? The importance of issues such as waste reduction and risk aversion are key elements in understanding why firms choose to invest in environmental management. During the same year, Porter (1991) discusses the greening of America, and the advantages of green business practices. Kleiner (1991) sets the stage for some of the constructs proposed in this dissertation. First, the article questions what it means to be a "green" firm. An answer to Kleiner's question, is that one measure of greenness is the extent to which a firm has a well-developed and integrated EMS. Other important considerations are the extent the firm or its executives are risk averse. The fear of environmental penalties in the form of fines and even jail time have prompted some managers to rethink their environmental policies (Davids 1994; Hunt and Auster 1990). Additionally, waste reduction is important to the nomological net of environmental business practices. When examining waste reduction, many of the papers in practitioner journals discuss the reduction of outputs such as hazardous wastes. To extend this line of thinking, waste reduction can include the approaches a firm has to the designing of products, manufacturing practices and waste reduction practices for hazardous and non-hazardous materials. Thus, waste reduction can impact much more than environmental performance.

Porter (1991a) reveals several "win-win" environmental situations. Walley and Whitehead (1994) discuss the idea that win-win situations are rare and overshadowed by a firm's total cost of environmental programs. Walley and Whitehead go on to suggest that firms should be looking to improve shareholder value instead of compliance, emissions, or costs. This approach of making "trade-offs" when firms address environmental issues seems very logical and the article is a smelling salt for those people enamored with the win-win best case examples suggested by Porter. During this time of the 1990s we find the further development of the paradigm that environmental business practices only impact environmental performance. Walley and Whitehead do a good job of countering the examples of Porter's earlier work, but offer no tangible resolution to the conflicting anecdotes. Interestingly, these conflicting paradigms are based on extreme case study examples that leave a large gap for researchers to fill.

Responding to controversy in the growing environmental field, several letters to the editor of Harvard Business Review and articles appear in a short period of time in this same journal (Clarke, Stavins, Greeno, and Bavaria et.a. 1994; Clarke, Cairncross, Walley, Whitehead, et. al. 1994; Porter and Van Der Linde 1995a). Porter and Van Der Linde (1995a) present a cumulative, or simultaneous approach to environmental business practices labeled "green *and* competitive: ending the stalemate." The article points out flaws in our regulatory system and processes that have set up the wrong type of environment for firms to correctly address pollution problems. The authors suggest a change in the regulatory process, and a change in industry's approach to environmentally conscious manufacturing. Industry should not spend resources fighting, or stalling the regulatory system, but should instead find ways to innovate processes and *simultaneously* eliminate waste. Again we see output measures and waste reduction as a primary concern when addressing environmental issues.

Porter and Van Der Linde (1995a) go on to introduce the idea of resource productivity: "innovations that lower the total cost of a product or improve its value allowing companies to use a range of inputs more productively and thus offsetting the costs of improving environmental impact." Porter and Van Der Linde discuss the shifting of thinking from end-of-pipe to proactive thinking. This proactive thinking hints at the extension of Total Quality Management (TQM) to Total Quality Environmental

Management (TQEM). Here we see a more explicit development of environmental innovations that impact not only cost, but also the elements of value. Implicitly, the authors suggest environmental innovations impact the elements of value i.e., flexibility, speed and lead time as defined by Melnyk and Denzler (1996). Thus, the research in this field supports an argument for why firms will want to invest in an EMS and the potential of resource productivity impacting more than just environmental performance Klassen and Whybark 2000a; 2000b).

To continue with the idea that environmental business practices impact more than just environmental performance we find a transition to some empirical work by Florida, (1996). Florida's research identified firms who innovative and adopt advanced manufacturing practices can simultaneously realize improvements in productivity and environmental performance. Florida's research, draws from surveys, phone interviews, and field research to explain the link between advanced manufacturing practices and environmental performance. While Florida states disagreement with the win-win approach of previous authors such as Porter and Van Der Linde, this research supports a simultaneous approach to improved environmental performance (Porter and Van Der Linde's argument) and does not support environmental business practices achieved at the expense of other initiatives (Walley and Whitehead's argument). This seems to parallel the same arguments of tradeoffs by Skinner (1969) and the cumulative approach of Ferdows and DeMeyer (1990) in the operations management field.

2.3.1 Business Literature Summary

The authors and papers reviewed thus far suggest different ways to look at environmental business practices and are for the most part normative and anecdotal in nature. While these researchers have stimulated interest in the topic of environmental business practices, what is overlooked in the literature to date is empirical validation of the hypothesized relationships. Few published empirical studies have undertaken hypothesis generation and theory testing (Klassen 1995; Florida, 1996; Dun, 1997; Curkovic 1998; Klassen 2000; Klassen and Whybark 2000a; 2000b). Still, we have not resolved the conflicting paradigms and find little empirical validation of environmental research.

Thus far, the literature reveals several key reasons why environmental issues are becoming important to firms, i.e., waste reduction, resource productivity, and improved firm performance. The review of the literature also reveals conflicting paradigms that have gone unresolved empirically. The following sections discuss the operationalization of the constructs found in the conceptual model in Figure 1.1. Theory development and resolution of the conflicting paradigms will come about through operationalizing the constructs, positing relationships among constructs, and finally testing the proposed model.

2.4 Sources of Uncertainty

The focus of this section is to support the relationships posited between the constructs internal uncertainty, external uncertainty, and EMS development. These relationships are hypothesized in the conceptual model in Figure 1.1 and developed in the following subsections.

2.4.1 Internal Uncertainty

Internal factors such as culture, management controls and behavior, operating procedures, risk aversion, competitive stance, or the rate of change in the industry or products all contribute greatly to the complexity of issues surrounding EMSs (Marguglio 1991; Dillon and Fisher 1992). While this dissertation will not tackle all of the types of internal uncertainty, some types of uncertainty such as management behavior and risk aversion are important to this research. The awareness of environmental issues and the ability of top management to take aggressive actions will play a significant role in the development and strategic impact of an EMS. The success of environmental initiatives depends on manager's leadership (Dillon and Fisher 1992). The use of "idea" people is important to the successful completion of environmental initiatives. For firms such as AT&T, Interfaces Inc. or Monsanto and Patagonia, the increased use of environmental champions becomes an important element in the development of environmental initiatives (BSR 1998). This use of environmental champions should therefore impact the development of systems such as an EMS.

Companies at different levels of internal uncertainty will have different levels of EMS development (Marguglio 1991). Marguglio goes on to posit that lesser developed firms will have no systems in place to assure awareness of changing environmental requirements. These types of firms typically do not have top management support for environmental programs and will be risk averse, in that new systems will not be developed proactively. Instead, the result of noncompliance issues, or industry mandates will induce system development. Additionally, these same types of firms will not have procedures that define methods for preventing noncompliance, or for aiding decision making. An EMS can provide these procedures and methods.

Another internal issue impacting the firm includes competitive stance. The concerns and objections to EMS center on several critical points. First, there is internal uncertainty that the benefits offered by EMS may not be sufficient to offset the costs incurred. Second, there is the relationship between environmental performance and corporate performance. To date, unlike the quality movement, where quality was shown to have a strong impact on corporate performance (Garvin 1986; Roth De Meyer and Amano 1990; Miller and Roth 1994), there has been little evidence offered which shows that there is a strong positive relationship between improved environmental performance and strong corporate/strategic performance (Klassen and McGlaughlin 1996). As a result, risk averse manager are hesitant to pursue environmental initiatives such as an EMS or anything labeled as "green" because, generally, they are not sure of the cost/benefit trade-off (Mroz, 1997). In addition, the standard for EMS is relatively new. Thus, a great deal of confusion and uncertainty surrounds the topic. Firms dealing with more aggressive competitors will rush to develop an EMS upon finding the competition has such as system. Managers that are more aggressive, less risk averse, and deal with aggressive competitors will be more able to develop an EMS than passive, risk averse managers with a "live and let live" philosophy toward the competition.

Much the same as technology adoption, a relatively small number of firms will proactively adopt and develop an EMS well ahead of the others, while some firms will wait until the competition or customers have forced this upon them (Moore 1991; Sroufe, Curkovic, Montabon, and Melnyk 2000). In industries with high degrees of technological change, and changes in the marketplace, firms may be accustom to these risks, the fast pace of change, aggressive competitors, and have top management that actively pursue new environmental initiatives.

Under the above internal uncertainty conditions, firms already dealing with a high rate of change in the marketplace and within their own product will benefit from a well developed EMS that can improve the competitive stance of the firm, and reduce uncertainty while aiding in decision making.

2.4.2 External Uncertainty

External issues impacting the firm include obsolescence, changing technology, demand predictability, the ability to predict competitor actions, and competitors all influencing the awareness a firm will have about competitive advantages through EMS. These agents, such as customers, and industry all impact the awareness of a firm to environmental initiatives and potential market niches. Borrowing from the general principles of industrial organization model (Bain 1956; Scherer 1970), the structure of the external environment will have an impact on conduct of the firm. For the external uncertainty construct, this posits that the structure of the external environment will have an impact on EMS development. This portion of the model generally borrows from the paradigm of industrial organization, and specifically from the Structure – Conduct - Performance (SCP) literature (Porter 1979, 1981, 1991a; Miller 1987; Rumelt 1991) that all claim the external environment will impact the conduct of the firm. The SCP posits that industry structure will dictate the actions necessary for firms within an industry that will in turn effect the performance of the firm. Additionally, the alignment between the external environment and firm strategy becomes important to enhanced firm performance

(Venkatraman and Prescott 1990). The relationships between the sources of uncertainty and the development of an EMS can explain a firm's motivation for pursuing EMS and under what conditions this may happen.

There are several reasons why a firm will experience external pressures. If a firm's customers are demanding "greener" products, then the firm tends to look for ways to improve image and marketability of it products to avoid obsolescence. Alternatively, some firms may believe this green movement is another marketing fad, and may choose to wait and see what competitors are doing before committing any resources to an EMS. Other customers and stockholders may also demand more environmentally conscious practices. Therefore, firms with a high the rate of product/service obsolescence may be reluctant to develop a system when the introduction of new products and the rate of change in the industry is very high. EMSs have the ability to meet the needs of firms in these fast-moving environments, but proactive development of an EMS may become to difficult and reactive development becomes more widely used.

If regulatory agents demand the company emits fewer hazardous materials, and demand and competitor actions are difficult to predict, then the firm will react in a different way. Begrudgingly at first, firms may accept this as a cost of doing business and invest only the minimum amount necessary for compliance. Some firms will not stray from this minimum "cost" approach to thinking, and are reactive at best. It may be that some firms require higher output price levels to be present to invest in environmental technologies because they would not want to commit to a heavy irreversible investment that may be unprofitable in the event of a price fall (Cortazar, Schwartz, and Salinas 1998). These same authors predict firms in industries with high output price volatility and low predictability of customers and competition will be more reluctant to invest in environmental protection technologies and will be more willing to operate at low output levels, thus attaining low pollution output levels.

The early adopters of a new technology stand to gain an advantage over other firms who are not seeking systems development early (Moore 1991). This advantage may well be the ability to shape regulatory policy or standards because the firm is benchmarked as an environmental leader in its industry (BSR 1998). Dean and Brown (1995) claim that some firms may acquire strategic benefits in this same manner. Firms who are willing to take a more strategic approach to environmental business practices should be able to integrate pollution prevention throughout the firm's practices and processes and use them to create long-term advantages (Rondinelli, Berry and Vastag, 1997). This argument would call for the proactive development of EMSs despite the unpredictability of customers and competitors. If we again look to the adoption of new technology and the Moore (1991) chasm model, there tend to be a small amount of firms that are so proactive as to adopt a new technology well in advance of everyone else in the industry. Therefore, it may be that most firms are reluctant to develop EMSs until customer's demand is predicted, and competitors are also using EMSs.

Sources of external uncertainty are due to obsolescence of products and services, changes in technology, customers, and changes in the marketplace. If customer demand and competitor actions were predictable, then every business would be successful and in possession of a well-developed EMS. Instead, the unpredictable marketplace and customers impact the ability of a firm to pursue the development of an EMS. Due to these and other factors, firms may choose to extinguish everyday fires, and not invest in the development of an EMS.

2.4.3 Summary: Sources of Uncertainty

The sources of internal uncertainty examined in this research include risk, changing technology, corporate culture, regulations, firm image, and changes in the marketplace. It is from these general concepts that the sources of internal uncertainty to include top management behavior, decision making trends, risk aversion, how the firm deals with the competition and rate of change involved in production and new products. The literature shows firms with aggressive top managers, high rates of change in the marketplace and within their own products can benefit from a well developed EMS that can improve the competitive stance of the firm, and reduce uncertainty while aiding in decision making.

The operational framework for external uncertainty involves industry obsolescence, the rate of change in product/service technology in the industry, the predictability of customer demand and the competition. Based on the literature and the knowledge of the researcher, there are external sources of uncertainty that appear to be causing apprehension about EMS development. In 1997, EMS standards were new and the relationships between environmental actions and the benefits were mostly untested.

2.5 Firm Effects

Some of the factors impacting the development and implementation of an EMS include the size of the firm, and resource availability. Size of the firm can be determined using sales information. Dillon and Fisher (1992) found that size did appear to determine the extent and nature of environmental programs, but that size alone did not appear to determine a successful outcome of environmental programs.

Due to the increased importance of the environmental issues internationally, customers may include environmental practices and the presence of an EMS in their supplier audits. Supplier audit information may become more important in those countries with environmentally oriented cultures such as Europe and Asia. Klassen and Angell (1998) note that German managers reported significantly higher levels of environmental ambition and lower levels of regulatory-driven motivation than U.S. managers. Therefore, the amount of European sales may also impact the status of the EMS. There is some evidence against this by Dillon and Fisher (1992) and several case studies that shoed no difference in practices or performance of US-based companies and those owned by foreign companies. The basic assumption is that the more the firm exports, especially to Europe, the greater the inclination to have a well developed EMS in place to help with international regulations and environmental supplier audits.

Additionally, the amount of sales to the end customer may also impact the development of an EMS. Those firms farther down the supply chain may not have the same requirements or incentives imposed on them as do the tier one suppliers of an Original Equipment Manufacturer. If the end customer requires environmental audits, or there is a possibility that certified EMS will be required for the supply chain (Bergstrom 1996; Daniels 2000), than it will be to the firms advantage to have an EMS to aid in this process.

Arora and Cason (1995) reveal companies emitting the largest amounts of toxic releases are the most likely to take part in a voluntary environmental program. This may also be true of EMS development. Since companies emitting the largest amount of toxic releases are typically concentrated in certain industries, examining an industry effect will be of importance to research in this field. Arora and Cason (1995) studied the EPA's voluntary 33/50 program. The author's results reveal that such voluntary programs may achieve substantial reductions because they target those forms with the greatest reduction potential. Arora and Carson show that firms with high toxic releases are more likely to participate in voluntary programs. This participation is consistent with an alternative interpretation that the public announcement of the Toxic Release Inventory data (and resulting bad publicity) induced firms to reduce toxic emission. The involvement in voluntary environmental programs may be due to past environmental infractions and pressure from outside constituents. This social desirability may be one reason for firms to look at waste reduction and pollution prevention with the help of an EMS.

Finally, the industry in which the firm operates will also impact the development of environmental systems and tools (Sroufe, Curkovic, Montabon, and Melnyk 1999). Industry can become the driving force for environmental improvement. The furniture industry has shown us that greener products can be an order winner if all other things (cost, quality and flexibility, for example) are equal (Handfield, Walton, Seegers, and Melnyk 1997).

2.5.1 Summary: Firm Effects

The operational framework for examining firm effects involves researching the relationships between several variables and the development of an EMS. These variables include industry, size of the firm, amount of exporting to Europe (specifically), amount of exporting (general), and sales to end customers.

2.6 Development of the EMS Construct

This section sets the stage for operationalizing an EMS. This section explores the beginnings of EMS through the lens of environmentally responsible manufacturing and through the development of the International Organization of Standards (ISO) EMSs standard 14000. By looking at both ERM and ISO 14000 a new definition of an EMS is developed.

2.6.1 Environmentally Responsible Manufacturing

Environmentally Responsible Manufacturing (ERM) is discussed in this section as a lead-in to the development of the EMS construct. Any discussion of the principles and practices of EMS requires not only a definition of what it is, but also a recognition of where EMS fits within this rubric of more aggregate concepts such as (ERM). While the working definition of EMS was given in Chapter One, this section of Chapter Two discusses ERM, the International Organization for Standards EMS standard, and how an EMS operational framework is developed from the literature.

Melnyk and Handfield (1995) define Environmentally Responsible Manufacturing (ERM) as a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing its effect on the environment while also trying to maximize resource efficiency. Compared to the other labels and definitions used to describe the integration of environmental issues into decision-making processes such as industrial ecology (Arthur D. Little 1991); environmentally operations management

(Gupta and Sharma 1996); environmentally conscious manufacturing (Sarkis and Rasheed1995), ERM is the most comprehensive.

EMS has become an important factor in the decision-making process of companies around the world. Traditional ways of dealing with environmental issues in a reactive, ad-hoc, end-of-pipe manner have proven to be highly inefficient (Global Environmental Management Initiative 1996). Thus, proactive environmental practices and the use of EMS to make decisions can make firms more efficient.

Environmental management practices have grown substantially in both size and importance, and the significance of their decisions has increased dramatically (Epstein 1996). Many companies (e.g., Procter & Gamble, 3M, DuPont, Monsanto, etc.) are reorganizing functional responsibilities, engaging the most senior executive in environmental oversight, elevating decision-making about environmental issues, spending substantial amounts of money to go well beyond compliance laws, and redesigning whole systems of resource use and production. With a system in place to aid in environmental decision support, and the dissemination of information, an EMS may be considered the cornerstone for the execution of ERM activities. There are many reasons why numerous companies have begun to take ERM very seriously. Some of the reasons for this increased attention include: criminal and civil liabilities, the fear of exposure as an obstructionist polluter, concern to attract environmentally conscious engineers and scientists, a sense of responsibility to neighbors, and customers are demanding it (Arthur D. Little, Inc. 1992; Reilly 1995). The competitive position of a company is strongly impacted by its response to environmental issues (Bavaria 1996). By properly implementing an EMS, any company, large or small, can ensure that they effectively manage environmental risks while identifying and exploiting the opportunities ERM can bring (Global Environmental Management Initiative 1996).

Substantial competitive advantages can also be achieved through ERM. Expected benefits of ERM include safer and cleaner facilities, lower future costs for disposal and worker protection, reduced environmental and health risks, and improved product quality at lower cost and higher productivity (Sarkis and Rasheed 1995). Companies have come to recognize that reduced environmental impacts and the institutionalization of ERM can lead to improved operations and profitability (Epstein 1996).

2.6.2 Summary: Environmentally Responsible Manufacturing

ERM is an important concept that can be realized through the use of integrated systems. EMS is a component of ERM and needs to be linked to operations management capabilities. The link between ERM systems and TQM systems is one that has already been established (Curkovic 1998).

When we look at defining the concept of EMS, it is a fundamental component of the ERM philosophy. EMS can be involved in the monitoring, tracking, summarizing and reporting of environmental information to internal and external stakeholder. With a well develop EMS there are opportunities to integrate cross-functional activities and include environmental training of personnel. Finally, a well developed EMS can include the formal procedures and the availability of these procedures and information to people in new product and process design.

What has not been explicated is exactly how an EMS is identified and how it can be integrated in a cross-functional setting? The next section helps to define EMS from the ISO 14000 environmental management standards.

2.7 International Organization of Standards 14000: Environmental Management Systems Standards

This section builds on the previous ERM section and helps to establish the definition of an EMS. By combining the ERM literature and ISO 14000 literature a better understanding of the EMS construct results.

Considered by some as being more environmentally conscious, European countries have developed environmental legislation and standards to promote environmental business practices (Klassen and Angell 1998). As a result of the many different regulations and standards, the International Organization of Standards (ISO) set out to develop one standard for EMS. One of the primary reasons firms have been interested in EMS is due to the International Organization of Standards release of the EMS standard in 1996.

Representatives from some 50 countries around the globe formally adopted the international standard on environmental management systems (ISO 14001) by the International Organization of Standards in the fall of 1996. This standard attempts to build on the success and experience of its predecessor, the ISO 9000 standards, and its variants such as QS 9000 within the automotive industry. If the ISO 14000 series of standards work as intended, it will set a higher level of expected environmental management practices worldwide. The operating premise is that the improved systems associated with the ISO approach will make achievement of performance goals more likely. Additionally, these new standards are predicted to facilitate trade and remove trade barriers.

The daunting task for U.S. multinational firms will be to implement uniform environmental management practices driven by the convergence of national compliance requirements and the matter in which they operate (Karls 1993; Walter 1994). However, the literature fails to describe how this can best be accomplished. Balikov (1995) suggests that ISO 14000 standards may serve this purpose best if the standard receives widespread acceptance.

2.7.1 The Need For Standards

Webster's Encyclopedia (1989) defines a standard as "anything, a rule or principle, that is used as a basis for judgment, an average or normal requirement, quality, quantity, level, grade, established authority, custom or by an individual as acceptable." Environmental standards, whether they relate to an organization's internal operations or across countries, establish a minimal level of acceptable performance and serve as a catalyst for improvement. Imai (1986) states "there can be no improvement where there are no standards."

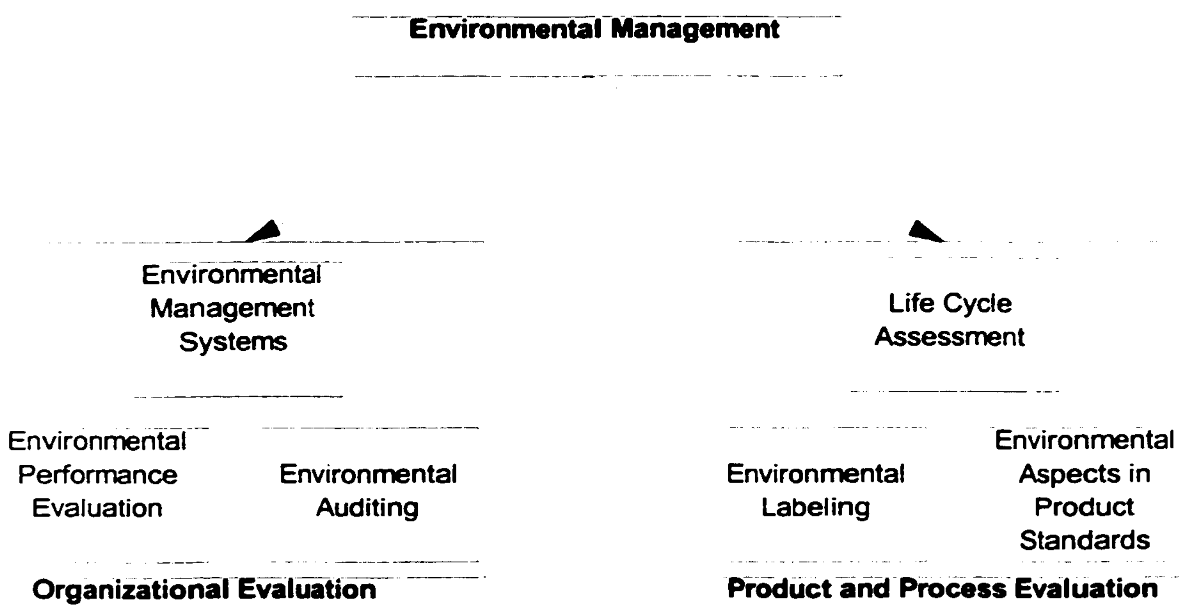
Much of the literature addresses how standards bodies, industry associations, regulatory agencies and companies have been working together to develop global guidance for environmental management. In Europe, there is the imposition of environmental management standards such as BS 7750 and ISO 14000. Even the North American Free Trade Agreement addresses the standardization of environmental issues among the U.S., Mexico, and Canada. Comparable developments are underway in the Pacific Rim nations. The U.S. - Asian Environmental partnership (US-AEP) was established in 1992 with the goal of promoting partnership between the U.S. and Asian countries in order to improve the environment of Asia.

For a better understanding of EMS standards we can look to ISO 14000 for guidance. The standard describes a system that will help an organization to achieve its own objectives and targets. The assumption is that better environmental management will lead indirectly to better environmental performance (Tibor and Feldman, 1996). The transition of the intent of ISO to the actual standard (14000) encompasses several standards in the following 7 general areas:

1. Environmental Management Systems (14001, 14004)
2. Environmental Auditing (14010, 14011, 14012)
3. Environmental Performance Evaluation (14015,14031)
4. Environmental Labeling (14020. 14021, 14022, 14024)
5. Life Cycle Assessment (14040, 14041)
6. Environmental Aspects of Product Standards (14060)
7. Terms and Definitions (14050)

These standards are then split into two general categories as shown in figure 2.1. The EMS, auditing, and performance evaluation standards are used to evaluate the firm. The EMS standards provide the framework for the management system. Auditing and performance evaluations are seen as management tools in the successful implementation of an EMS. Labeling, life cycle assessment, and environmental attributes in product standards emphasize the evaluation and analysis of product and process characteristics.

Figure 2.3 Intent of ISO 14000



A firm can implement an EMS that is in line with one of the EMS standards (BS 7750, EMAS, or ISO) without external certification. External certification and registration becomes a factor once there is a clear reason to demonstrate conformance to third parties. Some situations where certification could become important are (Tibor and Feldman 1996):

- A customer requires EMS certification as a condition to sign a contract.
- Your organization supplies to a customer who strongly suggests you become registered.
- A government provides benefits to registered organizations.
- You have a site in the European Union, where market pressure or the regulatory environment forces you to get registration or certification.
- A single international environmental standard can reduce the number of environmental audits conducted by customers, regulators, or registrars.
- You export to markets where EMS registration is a de facto requirement for entering the market.
- You expect to gain a competitive advantage through EMS registration.
- Your major stockholders (local community, shareholders, unions, etc.) expect environmental excellence and an EMS registration is the way to demonstrate it.

If one of the above situations applies, a firm should decide whether to get registration for the organization as a whole or just for parts of it. If the firm is already ISO 9000 certified, it makes sense to define its scope in a similar manner (Tibor and Feldman 1996). If the firm opts for a site registration, there is the advantage of not losing the registration for your whole organization if one of the sites does not comply with the requirements of the standard. Also the process of implementing, certifying, and registering the EMS is broken down into smaller projects that can be easier to handle.

To date, no empirical research has addressed whether ISO 14000 will be widely used by businesses as a consensus model, and whether it should be. Instead, the literature is saturated with conflicting predictions and views of extreme situations offered by experts. The champions of ISO 14000 suggest that it will unify countries in their approach to environmental management and will eventually be looked upon more favorably than traditional measures (Cascio 1996; Vierira 1996). One can argue that small manufacturing firms constitute the largest potential market for ISO 14000, and that the real test of the standard can be measured by adoption rates among these firms, which typically need the most direction in these issues. The development to watch is what industrial customers do with these standards with regard to their supply chains. Acceptance of the standard will come when conformance or certification becomes a condition for customer requirements. This suggests that the predisposition of corporations to ISO 14000 will mostly influence the adoption rates and ultimately, the success of this standard.

However, no research to date has examined the predisposition of ISO 14000 among managers of corporations. Miles and Russell (1997) call for research involving performance evaluations that include environmental concerns as well as recycling and waste reduction initiatives. Additionally, attitudes toward teamwork and cooperation with other employees (much the same as the systems based ISO 14000 approach) could be used in determining performance and salary increases.

With the intent of EMS standards discussed, a better understanding of why a firm chooses to develop an EMS hinges on several factions such as stakeholders, regulations, endogenous issues that are firm specific, and exogenous issues that include social desirability. Before attempting to better define what EMSs are, the following is a summary of the reasons for developing an EMS.

Figure 2.4 Why Firms Pursue EMSs

	Stakeholders	**Regulatory Environment**	**Firm Specific**	**Social Desirability**
Reasons for EMS	• Export to Markets that require EMS certification • Sell in International Markets • Customer Requirement • Stockholders Demand It	• Environmental risk to the firm • Government Incentives	• Competitive Advantage • Economies of Scale from joint ISO 9000 and 14000 Certification • Single EMS standard • Pollution Prevention • Reduce Violations • Corporate Culture • Environmental Commitment	• Improve Image • Reduce Environmental Impact of the Firm
Purpose of EMS	• Establish Policy • Identify Environmental Impacts of Products	• Identify Priorities • Establish Objectives • Identify relevant legislative requirements	• Establish Program to Implement Policies and Objectives • Facilitate Planning, Control and Monitoring for Compliance	• Documentation • ISO 14000 Certification or "proof" of an EMS

2.8 Defining EMS

EMS standards describe the elements of an effective environmental management system. These elements include creating and environmental policy, setting objectives and targets, implementing a program to achieve those objectives, monitoring and measuring its effectiveness, correcting problems, and reviewing the system to improve it and overall environmental performance. Therefore, the elements of the EMS have the ability to be firm specific and vary from one firm to the next.

To date, it can be argued that ISO 14000 standards may be the best framework for developing and documenting a structured EMS. For a better understanding of EMS standards we need to consider the following point: existing EMS standards are process not performance standards. In other words these standards do not tell organizations what environmental performance they must achieve aside from compliance with environmental regulation. Instead the standards describe a system that will help an organization to achieve its own objectives and targets. The assumption is that better environmental management will lead indirectly to better environmental performance (Tibor and Feldman 1996) and even increased profitability (Dechant and Altman 1994). While many believe in the link between firm performance and EMS, the question still remains; can EMS lead to enhanced profitability? There is a clear need for empirical testing of this research question.

2.8.1 EMS Attributes

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

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

2.8.2 Indicators of Commitment to EMS Development

Top management support will be a determining factor for the development and completion of an EMS. Evidence of a firm's commitment to EMS can be identified in the following ways; (1) A senior corporate official has been assigned to implement the policy; (2) Lines of responsibility and accountability have been identified (e.g., environment is considered part of performance evaluation, and procedures are documented) ; (3) Goals have been defined that are measurable; (4) Adequate resources have been allocated to implement the program. A related key program element is whether the corporation has developed systems to assist in implementing the program, measuring performance, such as environmental accounting systems and monitoring systems that track emissions and discharges of pollution as well as the usage of raw materials, energy, and other inputs to production.

Even if a firm has developed superior environmental management systems, ultimately, it is critical that these efforts lead to improvements in environmental performance. Firms must be able to demonstrate that they are making progress toward reducing pollutant generation and releases and minimizing liability exposure. Producing documentation of waste generation, effluent discharges, spills of hazardous substances, and the like is both analytically tractable and, increasingly required by regulatory agencies and company stakeholders. The best firms in this regard set and achieve goals that are more stringent than those explicitly required by law. In an interesting parallel with corporate financial reporting, some firms have even moved toward obtaining independent audits to enhance the credibility of their stated environmental performance.

A firm's commitment to an EMS will be a determining factor in the success of the system and the extent of the benefits derived from environmental efforts. Still there is a need to better understand the extent of commitment found in ERM firms, and the relationships between EMS and firm performance.

2.8.3 Implementing an EMS

Implementation an EMS requires a range of activities: 1) training to ensure that workers operate equipment and production processes correctly and are proactive with respect to addressing environmental risks; 2) product design and development approaches (e.g., Design for Environment) that reduce the usage of raw materials and generation of hazardous waste; 3) environmental risks assessment throughout the product life cycle; 4) and monitoring to ensure that manufacturing operations are in compliance with pollutant emission standards and other regulatory requirements. Additionally, there is an important aspect of corporate culture in which awareness of and performance related to environmental issues is valued and rewarded. Functional areas other than the environmental or legal experts need to know why the firm is developing an EMS, and what everyone needs to do to meet the certification goals.

During the course of EMS development or improvement, several distinct and important EMS functions that are not being performed well or at all may be identified. These deficiencies may be addressed through specific infrastructure enhancements in the designing of products or processes, or through investments in the capabilities of the organization's human or information management resources. Conducting a purposeful knowledge/skill building initiative is often a critical activity on the path toward improved environmental and business performance. Similarly, effective environmental management systems require timely and high quality information, so information management analysis or improvement activities can play a pivotal role in helping the organization to meet its environmental improvement goals. Communicating accomplishments efficiently, clearly, and credibly to all interested stakeholders is very important (Feldman, Soyka, and Ameer 1997).

Implementation, like the other aspects of EMS lacks generalizable research as to the best practices or approaches to ISO certification. What firms need are the compelling reasons to implement an EMS and frameworks for current practices.

2.8.4 Summary: Environmental Management Systems

In summary the EMS standards have the same set of basic elements. These elements are much the same as the Deming cycle and include: (1) creating an environmental policy; (2) setting objectives and targets; (3) implementing a program to achieve those objectives; (4) monitoring and measuring its effectiveness; (5) correcting problems; and, (6) reviewing the system to improve it and its overall environmental performance. However, while the elements are somewhat common, it is the special information the system can generate that serves to differentiate the EMS of one firm from that of another. Thus, many firms can have an EMS, and each of these systems can be a unique resource, delivering specialized information to individual firms. The elements of an EMS are still very vague. Many questions still remain about what constitutes an EMS. The presence of an operational framework can help better define an EMS. Attributes for this framework include the following:

- The presence of an environmental management system.
- There is top management support of EMS.
- The presence of a formal environmental report.
- Environmental procedures that are formally documented.
- Environmental procedures are made available to employees.
- Environmental performance is formally tracked and reported
- Environmental issues are included in training.
- Establish an environmental policy appropriate to the organization.
- Identify the environmental aspects of the organization's products, services, and activities to determine both impact and significance.
- Identify priorities and establish objectives.
- Facilitate planning, control, monitoring, and changes to ensure policy is complied with and remains appropriate for the organization.
- Be ready to adapt to changes in the business environment.
- Identify the relevant legislative and regulatory requirements.

Based on the literature review, a new definition of EMS can be developed. For the purposes of this dissertation, the definition of an EMS is:

> 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 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, and focuses on the outputs of the firm, and is used to enhance firm image.

The operational framework for EMS involves both ERM and the ISO 14000 standards. Borrowing from ERM we find that EMS should be involved in the monitoring, tracking, summarizing and reporting of environmental information to internal and external stakeholder. There is also the need for integrating cross-functional activities to include environmental training to personnel. Finally, there is the need for formal procedures and the availability of these procedures and information to people in new product design, process design, and packaging.

Insight from ISO 14000 helps the operational framework of EMSs by identifying the intent of EMSs. The purpose of EMS impacts different internal and external stakeholders. EMSs should help to establish policy, identify environmental impacts and objectives, document processes, help performance, collect information through environmental auditing, pollution prevention, show environmental commitment, and improve environmental corporate culture.

The literature review has looked at sources of uncertainty, firm effects, ERM, ISO 14000, and the origins of EMS. Next, the literature review will provide insight as to the types of environmental practices a firm considers and the impact on firm performance. The environmental practices of the firm include the design of products called Design for Environment, manufacturing, and waste reduction practices.

2.9 Environmental Practices

This section introduces several different environmental practices a plants are involved in. This section first discusses Design for Environment and product design issues. Next, environmental manufacturing practices are developed, and finally, environmental waste practices are examined.

2.9.1 Design for Environment (DfE)

This section starts with a discussion of Design for Environment (DfE) and then proceeds to discuss product and process design, reduction, substitution, and recycling. The concept of DfE originated from industry's effort to target specific environmental objectives for design engineers to incorporate when creating a new product. DfE basically involves the incorporation of environmental considerations into product and process engineering design procedures (Allenby and Fullerton 1992). The goals of ERM can more easily be achieved when environmental issues are identified and resolved during early stages of product and process design, when changes can be made to reduce or eliminate environmental waste (Allenby 1993).

To date, a few case studies look at methods for achieving DfE goals within manufacturing process techniques (McCormack and Jin 1995; Sheng, Willis, and Shovita 1995). Research on manufacturing processes characterizes waste streams from specific processes (such as machining), and makes assessments of alternative processes. As such, specific DfE models have been developed and made available to practitioners. While it appears that much progress has been made in developing these models, they have not been integrated with one another to create a management system that allows for assessment of overall DfE performance and the trade-offs therein. Most of these studies argue that the greatest opportunities for waste minimization exist during the design process. Therefore, product designers need to understand the ERM process and be able to influence "green" process design. Instead, top management neglect, cost and regulatory constraints, the slow corporate decision making process, and cost-rather than engineering-based design evaluations are cited as obstructing environmental issues from being an integral part of product design (Bhat 1993). EMS may be the best approach to integrating environmental design practices into ERM processes and procedures.

2.9.2 Product/Process Design and DfE

The use of green design is increasing (BSR 1998). This increased use of design to realize environmental performance should not be surprising, since the design process is one of the major tasks for any firm. This process is responsible for two major types of design activities: (1) new product design and development, (2) process design and development. Both product and process design are closely interrelated and greatly influence each other while simultaneously impacting the environment. Both aspects must be considered to ensure that the firm has developed and implemented effective and efficient designs and processes. These design activities, in general, present opportunities for firms to find solutions to environmental issues (Lozada and Mintu-Wimstatt1995). These two design activities, when combined, shape the scope of the transformation process by determining the types of inputs required and outputs created. Inputs involve information about the substitution of lesser hazardous alternatives for previously hazardous materials. Through the use of an environmental design approach, products and processes are designed such that emissions and wastes are either minimized or completely removed (Tibor and Feldman 1996). Additional practices impacted by design include the ability of the firm to use substitute materials for products, reduce waste associated with product and process design, recycling, and the ease of disassembly of the product.

The NPD process embodies all of the steps necessary to take the product from concept to full production. Recently, this process has undergone extensive revision and rethinking (Hall 1993; Patterson 1993) due to increased market pressures to reduce the total cycle lead time (from concept to full production), reduce cost, enhance product flexibility and improve product quality (Cohen and Apte 1997). These pressures, are some of the same forces that impact developments such as TQM, JIT, and Time Based Competition (TBC) (Stalk and Hout 1990; Carter and Melnyk 1992) and Mass Customization (Pine 1993).

One can envision the NPD (i.e. product/process design and delivery system) as consisting of seven linked stages (Meyer 1993, pp. 193-228): advanced research, product concept, product specification, product development, pilot product, production, and finally, reincarnation/disposal. In all stages of the NPD process, environmental factors must be considered in addition to all other objectives and issues (Peattie 1992). Furthermore, one function or group no longer manages each activity in isolation. Rather, there is integration of multiple groups or stakeholders, both internally, with other functions, and externally with stakeholders, customers and suppliers. An example is found in AT&T's arrangements in which Lucent Technologies takes back, recycles, and reuses the switching equipment it suppliers to AT&T (BSR 1998). In the earlier stages of NPD, meeting the needs of stakeholders "such as regulators" is important. In the later stages of NPD, working with suppliers such as Lucent Technologies, customers, special interest groups and third party endorsement of products becomes important (Polonsky and Ottman 1998; Polonsky, Rosenberger, and Ottman 1998).

The end of the NPD process creates several important outcomes, such as the design and introduction of the product, the determination of the types and quantities of materials used and various manufacturing processing characteristics (i.e. equipment needed). When taken together, the product design process sets in place the material and capacity requirements, while also establishing the cost and performance traits of the product. This process also determines the types and timing of waste streams created and when these waste streams will be created. Nike used the DfE approach to eliminate the use of 800,000 gallons of solvents in its adhesives in 1997, and plans on reducing volatile organic compounds per unit of production 90% by the year 2001 (BSR 1998).

Cross-functional implementation of DfE is a complex company-wide issue. The American Electronics Association's Design for Environment Task Force has identified two important tools to aid implementation (Allenby and Fullerton 1992). The first tool is a DfE template, a generic set of procedures and practices that could be modified by individual firms depending on their existing design practices, level of sophistication, and other requirements. In other words, the DfE template would be derived from and compatible with existing design systems and would help guide firms in deciding how to fit DfE into existing design practices. The second tool is that of a Design for Environment Information System of (DFEIS). The DFEIS is the database supporting the use of the DfE methodology or template. Basically, the DFEIS is another term for an EMS and helps support the theoretical linkage between the EMSs and environmental practices.

2.9.3 Manufacturing Practices

Results from McKinsey and Company (1991) show production being perceived as the most critical phase of a product's life i.e., sourcing, production, use, and disposal. With this recognized importance come many labels used to describe environmental manufacturing practices, such as industrial ecology (Arthur D. Little, 1991) environmental operations management (Gupta and Sharma, 1996), environmentally conscious manufacturing (Sarkis and Rasheed,1995), environmental technology portfolio (Klassen and Whybark 2000b), and environmentally responsible manufacturing (Melnyk and Handfield, 1995). Interesting aspects of these environmental practices include the use of feedback loops for materials and products. This dissertation focuses on those manufacturing practices that allow plants to utilize cross-functional practices to consume internal wastes and look at practices such as remanufacturing or rebuilding products.

Since manufacturing practices are strongly cross-functional in nature, to be successful from both a corporate and marketing perspective, the product design activities must consider the perspectives of multiple parties and stakeholders (Polonsky and Ottman 1998; McDaniel and Rylander 1993). Included are areas such as marketing, product engineering, finance, manufacturing, production and inventory control, accounting, manufacturing engineering, quality assurance, top management, stockholders, suppliers, government, competitors, special interest groups and the customer. This cross-functional approach helps integrate information about the ability of the firm to remanufacture, or rebuild a product (such as Xerox and the used copier market).

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

Overlooked in the before mentioned studies are the concepts of remanufacturing and rebuilding products. Remanufacturing and rebuilding products is really an attempt to provide greater value to customers with fewer materials. It appears that firms are always 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 2000b), is through environmental manufacturing practices.

2.9.4 Waste Practices

One of the main reasons for firms to reduce waste involves the control of costs (GEMI 1997). Royston (1980) also emphasizes control of costs and pollution abatement through waste detection, and selling residuals as raw materials. Additionally support for this approach to cost reduction and waste management is found in Hart and Gautam (1996). Hart and Gautam's research also finds a link between emission reductions and firm performance. Based on the findings of previous research, one assertion of the proposed research is that environmental waste practices are impacted by the EMS and in turn can impact firm performance (GEMI 1994). Companies such as Dow Chemical and 3M have demonstrated the link to firm performance with programs such as Waste Reduction Always Pays (WRAP) and Pollution Prevention Pays (3Ps) respectively. Dow's WRAP program saved the firm over $20 Million a year in 1993 and 1994 in waste reduction.

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 dissertation include creating a market for waste materials, or consuming internally (i.e., reusing) waste materials. These waste related practices involve innovations that lower the total cost of a product or improve its value allowing companies to use a range of inputs more productively and thus offsetting the costs of improving environmental impact as defined by Porter (1995a).

2.9.5 Practices Summary

Environmental practices are new constructs that vary widely across firms and are impacted by the extent to which there is a well-developed EMS. The operational framework for environmental practices encompasses several types of actions a firm can take. These practices come in three general forms (design, manufacturing, and waste). This research is not attempting to demonstrate a temporal relationship between the different types of environmental practices. Instead, the model and research performed in this dissertation attempt to demonstrate that these practices do exist in industry and that they have mediating relationships with firm performance.

2.10 Performance

This section describes the potential benefits to firm performance that come about from different environmental management practices, programs and systems. These benefits and the theoretical linkages of the proposed model in Figure 1.1 are based on the resource-based view of the firm, the natural resource based-view of the firm, and corporate social performance. This section is broken out into a discussion of each of thee theoretical underpinnings.

There are many reasons why EMS should be potentially attractive to firms. First, there is the increasing use of voluntary standards in industry (i.e., ISO/ QS 9000).

Second, we see the potential of EMS becoming important to supply chain members (Rondinelli and Vastag 1996). Third, government adoption of EMS standards (Wheeler and Afsah 1996). Fourth, is the potential of EMS to reduce insurance rates (Greenwald, 1997). Fifth, pollution prevention leading to reduced costs of production and higher profits (Dechant and Altman 1994; Makower, 1994; Russo and Fouts 1997; Feldman, Soyka, and Ameer 1997; BSR 1998). Sixth, the increased importance of corporate social responsibility (Wood 1991; Pava and Krausz 1996). Finally, the ability to help the firm achieve environmental excellence (Melnyk, Tummala, Calantone, and Goodman 1996).

Firms which react to new environmental issues and regulations with end-of-pipe (e.g., scrubbers on smokestacks is at the end of the pollution proverbial pipe) solutions to pollution problems are the first to say that environmental regulations have only added to the cost of doing business. Proactive firms, such as Dow Chemical claim that environmental initiatives are expected to yield a 30 to 40 % return on investment by the year 2005 (BSR 1998). Additionally, firms such as Quad/Graphics Inc. have experienced competitive advantage by encouraging state regulators in West Virginia to establish very high performance standards for air emissions that only Quad/Graphics could meet and its competitors could not. Additional support for the link between environmental practices and firm performance can be found at Electrolux where in 1997, it reported its most environmental product line accounted for 10% of sales and 15% of profits.

Dean and Brown (1995) show that environmental regulations can influence rates of new firm entry across a broad rang of manufacturing industries. While an EMS is not a regulation, it can be a resource used to deal with regulations that is hard for other firms to perfectly imitate and poses new barriers to entry and mobility that many firms may not have yet contemplated. The need for developing an EMS is found in one of the items on a "wish list" of firms considered environmental leaders. This item involves the idea of a centralized database with practical information on environmental products, materials, recyclability, supplier information and so on (BSR 1998). Firms that have an EMS (such as the one suggested) in place have better systems capabilities to allow them to function in new industries. To better understand of the decision to implement an EMS, and the forces driving the need for this type of management system, attention needs to turn tothe ways benefits develop when firms have an EMS.

2.10.1 The Resource Based View of the Firm

The relationship between a firm's resource capabilities and competitive advantage has been well established in literature as far back as Penrose (1959) and Andrews (1971), and more currently Barney (1991); Peteraf (1993); Rumelt (1984), Klassen and Whybark 2000b). What will be the next source of competition advantage for multinational firms? The answer could be the systemic approach to greater efficiencies gained from EMS. One of the most important tasks for U.S. multinational firms will be to implement uniform environmental management practices and policies as they are driven by the convergence of national compliance requirements (Karls 1993; Walter 1994). However, the literature fails to describe how this can best be accomplished. Balikov (1995) suggests that EMS standards may serve this purpose best if these types of management systems receive widespread acceptance.

EMSs are becoming increasingly important to both national and multinational firms. The premise is that improved systems associated with EMSs will make achievement of performance goals more likely (Tibor and Feldman 1996). Additionally, new standards such as ISO 14000 are predicted to set a higher level of expected environmental performances worldwide, facilitate trade and remove trade barriers (Curkovic, Handfield, Melnyk and Sroufe 1997). Many questions surround the role of these types of systems in the strategic management of a firm. The primary question addressed here concerns the role of EMS in providing a competitive advantage. This section will provide a review of the management literature as it relates to EMS, and generate theory as to the use of EMS as a competitive advantage for the firm. Additionally, this section will explore the following questions:

1. Can EMS enhance profitability?
2. How does EMS effect manufacturing processes and waste streams?
3. Will firms with EMS have less risk?

These questions are explored by first reviewing the resource-based literature and then expanding on this literature review by looking outside of traditional strategy and management literature to other disciplines for insight into the integrated approach of EMS. Then following sub-sections focus on the evolution of the natural-resource-based view of the firm, and the forces behind the greening of business are identified. Next, the benefits of EMS are identified and propositions are put forth.

The importance of a firm's resource capabilities and competitive advantage has been well established in literature. The resource-based view of the firm posits that competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). These resources are considered valuable, rare, and in fact raise barriers to imitation, and entry (Barney 1991). Competitive advantage is rooted inside a firm, in these resources and assets that are valuable and inimitable (Itami 1987; Wernerfeldt 1984; Peteraf 1993).

Rumelt (1984) presents a simple theory of strategy in which a firm's strategy may be explained in terms of the unexpected events that created, (or will create) potential profitability together with isolating mechanisms that will act to preserve them. These isolating mechanisms, or barriers identified by Rumelt include:

Causal ambiguity	Unique resources
Specialized assets	Special information
Switching and search costs	Patents and trademarks
Consumer and producer earnings	Reputation and image
Team embodied skills	Legal restrictions on entry

The importance of isolating mechanisms in business strategy is that they are the phenomena that make competitive positions stable and defensible. Many of them appear as first-mover advantages (Rumelt 1984; Wermerfelt 1984). If a firm waits until the proper methods for entering markets or producing products is fully understood it will normally be too late to take advantage of the information (Rumelt 1984). It is here that we see the potential of being the first to adopt an EMS as a unique resource that can provide special information (e.g., costs of wastes leaving the firm in the form of liquid, solid or gases, documentation for auditing and public environmental information) both internally and externally to the firm. An EMS can provide information that can be used to aid decision making, enhance firm image, or if part of a certified standard, can facilitate entry into markets having legal restriction on entry to only those firms with a certified EMS. Borrowing for Melnyk and Denzler (1994) and the resource based view of the firm, a unique resource such as an EMS can provide specialized information that can enhance the value equation (e.g., quality, speed, flexibility, and costs).

2.10.2 The Natural Resource-Based View

A new and different approach to traditional resource-based views of the firm looks at the "environment" in a new way. According to Starik and Rands (1995), organizations have environmentally oriented interactions with other levels and systems, internal and external to the firm. These interactions are in what is called a web of relationships. The multilevel interactions exist, whether planned and/or recognized. At the enterprise level of strategy, managers should ask "what does our organization stand for?" and "what is our role in society?" Stark and Rands go on to claim managers need to adopt sustainable corporate-level strategies that develop lines of business that have low depletion and pollution impacts, and divest in lines of business that have the opposite effects.

An emerging theory is the natural-resource-based view of the firm. This natural-resource-based view is centered on the premise that business (markets) will be constrained by and dependent upon ecosystems or (nature) (Hart 1995). Suggesting that strategy and competitive advantage in the coming years will be rooted in capabilities that facilitate ecologically sustainable economic activity (Hart 1995; Jennings and Zandbergen 1995; Magretta 1997).

2.10.3 Value Chain Performance

From research efforts at Michigan State University, there is an increased need for companies to look down the supply chain and assess suppliers on "green" dimensions (Handfield, Walton, Sroufe, and Melnyk 1999). All things being equal (cost, quality, and flexibility), many firms would rather choose a supplier with better environmental performance than other higher environmental risk suppliers. With companies such as Ford Motor implementing EMS and ISO 14000 certification at all North American manufacturing facilities, EMS is an environmental management tool that many of Ford's suppliers will undoubtedly have to be paying very careful attention to (Bergstrom 1996; Daniels 2000). This "web" of relationships (Starik and Rands 1995) with suppliers now takes on a new performance dimension. Internal and external factors together determine a firm's awareness of EMS benefits. The level of awareness leads to the decision about EMS implementation and consequently to the EMS results.

If firms require it of their supplier, then the benefits of having an EMS need to be demonstrated. Russo and Fouts (1997) provide some evidence of the link between environmental performance and economic performance in high growth industries, while Pava and Krausz's (1996) literature review of Corporate-Social-Responsibility found nine empirical studies using environmental performance criteria to predict financial performance. Of these nine studies, four reported a positive association, while none of the studies reported a negative association with financial performance. There is additional evidence that firms recognize the before mentioned positive associations with financial performance, and go beyond compliance and position themselves for future changes in environmental policy (Business Week 1990). In fact, firms making investments in environmental health and safety initiatives that are not required by international laws or social standards, and are not in the interest of maximizing short-term profits, find the investments do pay off in the long-term (Rondinelli and Vastag 1997). Feldman, Soyka, and Ameer (1997) show that companies investing in environmental improvements could lead to a reduction in perceived risk (Dun 1997) with an accompanying increase in stock price of perhaps 5%. Additionally, an Arthur D. little survey of executives at 115 large North American businesses found that 61% expected meeting ISO 14000 requirements will bring a potential competitive advantage.

When EMS is considered part of proactive business practices, than additional advantages may include; introduction of environmental improvements ahead of the competition, the reduction of new product development cycle time, and unique information to aid the cost/benefit decision making process. In most cases, a thorough strategic assessment of environmental issues will identify areas of weakness in the manufacturing function that can be addressed through targeted EMS development and improvement initiatives. Florida (1996) found firms leveraging their industrial modernization strategies toward environmental ends and that firms see pollution prevention as important to overall corporate performance. EMSs are by nature firm and product specific, but often include an assessment and analysis phase and a development and improvement phase, the latter of which is focused on formulating missing elements (e.g., policies, procedures), integrating important EMS principles and tools, and establishing strategies for achieving desired patterns of internal and external information flow. It is from this EMS assessment and analysis phases that firms will be able to obtain information they may not have captured or tracked before (i.e., costs of different kinds of wastes), and move toward continuous improvement of waste reduction.

Beyond the disclosure of information to the general public, investors are also interested in the environmental initiatives of publicly held firms. How would an executive of a firm react to finding that investors are now looking at environmental attributes of firms when determining risk and making investment decisions?

Organizations such as Kinder Lydenberg, and Domini KLD & Co. provide social research on environmental attributes of corporations for institutional investors. Additionally, the Environmental Information Service at the Investor Responsibility Resource Center, in Washington D.C., collects, tracks and disseminates corporate environmental information to interested investors. If investors use this pollution information in making investment decisions, as empirical evidence indicates (Freedman and Jaggi 1982; Makower 1994; Pava and Krausz 1996), then meaningful pollution prevention information such as having an EMS, or EMS certification should benefit the firm. Ultimately, EMS can result in significant economic benefit beyond insurance premium savings (Greenwald 1997).

2.10.4 Corporate Social Performance

Benefits also include using an EMS as a means for companies with typically bad environmental practices to demonstrate a change in ways (Litskas 1999), or improved corporate social performance (Waddock and Graves 1997). This improved social responsibility can be seen as a product the firm has to offer to the key publics of the firm (Murry and Montanari 1996). Firms can build trust by being environmentally responsible and not denying pollution problems (Berry, Rondinelli, and Vastag 1996). Socially responsible actions of the firm hold the potential for promoting positive acceptance of the organization, thus increasing its competitive position in relationship to its industry rivals.

Given the social importance of environmental practices, how do stakeholders get this information? Many firms in the US and Europe report their environmental performance (Krut and Drummond 1997). Through the dissemination of environmental performance information, firms can build trust by showing environmental responsiveness and not denying any wrong-doing (Berry, et. al. 1996). Society is demanding social responsiveness at a minimum, and the call for social responsibility seems to be getting louder and clearer (Pizzolatto and Zeringue, 1993).

2.10.5 Summary of EMS Benefits

There are several EMS benefits managers and researchers should be interested in. The benefits to the firm go far beyond environmental performance and internal reporting. EMS has the ability to improve the internal and external tracking and reporting of specialized environmental information about products, processes, and performance. The operational framework for this construct consists of the following impacts on firm performance:

- Improved "value" performance (cost, quality, speed and flexibility).
- Improved corporate social performance.
- Reduced stock risk, and improved stock price.
- Provide more information to investors.
- Potential for a competitive advantage.
- Pollution prevention and waste reduction.
- Improved reputation.
- Improved supplier assessment.

2.11 Chapter Two Summary

Chapter two is not comprehensive in that every article ever written is reviewed for its potential impact on EMS research. Instead, this chapter reviews several critical literature streams of environmental business practices and EMSs in the fields of operations management, strategy, new product development, and marketing. Viewing EMSs as the overlapping area of these different literature streams, we gain greater insight to the integrated approach to improved firm performance through information systems such as an EMS. This chapter sets up the theoretical foundation for the constructs highlighted in conceptual model (Figure 1.1). The theoretical foundation for the proposed research is based in the structure – conduct – performance paradigm and supporting theories from the resource based view of the firm and corporate social performance. These theories establish the operational frameworks for the sources of uncertainty, the development of an EMS, the environmental practices a firm pursues, and the impact on firm performance.

CHAPTER 3

PRE-RESEARCH AND RESEARCH DESIGN

3.1 Introduction

As shown in Chapter Two, there has been a great deal of confusion about the definition of EMSs and the potential of an EMS to impact both environmental and non-environmental firm performance. To resolve the conflicting paradigms in the literature, attention turns to theory development and testing. Using a theory driven approach, Chapter 3 helps show the conceptual framework that will integrate several constructs and show the linkages that become the conceptual model. This model will in turn direct the empirical research of this dissertation.

This chapter will first discuss the theoretical propositions used to development the operational research propositions and hypotheses. Next, the research design lays out the approach to a survey instrument development, field studies, and summarizes information about the respondents. Finally, the proposed research methods are examined and limitations of the research are discussed.

3.1.1 Theory Development

This section of the dissertation defines the constructs, discusses the measures, and posits propositions and hypotheses. Theory may be viewed as a system of constructs and variables in which the constructs are related to each other by propositions and the variables are related to each other by hypotheses (Bacharach 1989). A good theory is a clear explanation if how and why specific relationships lead to specific outcomes. Since EMSs are new, most of the constructs are not well developed and a large number of manifest variables are used to capture the necessary validity and reliability underlying the proposed latent constructs (Hunt 1991). This approach starts with propositions derived from our knowledge of the field and certain assumptions. Next, we arrange these propositions into a model based on our assumptions and hypothesized theory. Finally, we analyze this model and attempt to deduce generalizations. The following theoretical model is derived from the literature, interviews with managers, research projects with the Michigan State University Manufacturing Research Consortium, National Science Foundation research projects, and this researcher's knowledge of the field.

The goal of the proposed dissertation is the investigation of the theoretical linkages between EMS and firm performance by answering the following primary questions:

1. How can we better define EMS?
2. What is the impact of EMS on firm performance and what factors influence EMS development?

Examination and analysis of the constructs and proposed model will answer the primary research questions. While case studies and deductive arguments have highlighted the costs and benefits of EMS, little research has been devoted to support these arguments with systematic empirical analysis. Operationalizing the constructs in Chapter Two, develops summated scales for the constructs and an understanding of how constructs are theoretically liked to the other constructs in the model. The next section explicates the relationships between the operationalized constructs.

3.2 Research Propositions and Hypotheses

The model in Figure 1.1 contains 7 different constructs: External Uncertainty, Internal Uncertainty, EMS Development, Design Practices, Manufacturing Practices, Waste Practices, and Operations Performance. The antecedents of EMS attempt to explain the relationship between sources of internal and external uncertainty and EMSs. Also within the model is the relationship between several manifest variables that are part of "firm effect" and the hypothesized relationships of these variables to EMS development. This aspect of the model will attempt to show the relationship between firm size, resource availability and exporting on the status of the EMS system.

Information in this chapter will then develop the relationships between different types of environmental practices a firm is involved in (Design, Manufacturing, and Waste) and their relationship with improved firm performance. The relationships between environmental practices and perceived firm will be tested to demonstrate the mediated relationship of EMS development and firm performance. The relationship between EMS development and firm performance is also tested directly. Of key importance are the direct and indirect relationships between EMS and firm performance.

Finally, the holistic model helps to explain and predict why firms will want to invest in an EMSs. The full model highlights the attributes of EMS development, relationships of uncertainty and EMS development, and environmental practices. Finally, the relationship of an EMS to improved firm performance provides an important relationship that is of interest to both managers and researchers. The following sections discussion each of the constructs and posited relationships.

3.2.1 Sources of Uncertainty

The concerns and objections to environmental business practices and EMS center on several critical points. As described in Section 2.4, internal uncertainty may be correlated with top management's decision-making policies, risk aversion, and the rate of change the firm is subject to. To date, unlike TQM and ISO 9000 which focused on quality (and where quality was shown to have a strong impact on corporate performance), there has been little evidence offered which shows a strong positive relationship between improved environmental performance and strong corporate/strategic performance (Klassen and McLaughlin 1996). As a result, many managers hesitate to pursue environmental initiatives such as the development of an advanced EMS or anything labeled as "green" because they are not sure of the cost/benefit trade-off (Mroz 1997). This internal hesitation closely resembles the apprehension to the introduction of systems such as Material Requirements Planning (MRP) systems. MRP is one of the most widely used manufacturing planning and control systems in industry (Clode 1993; Turnipseed, Burns, and Riggs 1992). Yet, at the beginning of the MRP introduction there was a great deal of resistance to this new technology due to inertia and huge investments shrouded in classic Operations Management (OM) systems. Since its introduction in the early 1970s, MRP has made extensive inroads with industry. There have been several reasons for the widespread acceptance of MRP. These include improved customer service, better production scheduling, and reduced manufacturing costs (Ang, Sum and Chung 1995; Schroeder, Anderson, Tupy and White 1981; Ang and Quek 1995).

The OM system involves everyone from executives to the personnel involved in production, purchasing, and marketing. Firms having key executives that aggressively pursue growth opportunities will be more inclined to invest in an EMS. Also, if the firm has environmental champions' i.e., people who are considered environmental leaders in their field, than executives who use these "idea" people for new projects will be more inclined to invest in an EMS. In general, if the internal environment is one in which new opportunities are explored aggressively, then there is a higher probability that the firm will have a more advanced EMS.

The construct "Internal Uncertainty" is measured by seven manifest variables. These sources of internal uncertainty (Appendix 1.) include:

- Top manager's belief that the competitive nature of the environment (not green environment) is either gradual or bold.
- When confronted with decision-making situations involving uncertainty, the company is either cautious or bold and aggressive.
- Risk taking by key executives of the company in seizing and exploring "chancy" growth opportunities has either decreased or increased.
- Seeking of unusual, novel solutions by senior executives to problems via the use of "idea people," brainstorming, etc. has become either less or more common.
- In dealing with its competitors, the company either resorts to a live and let live philosophy, or is more aggressive
- The rate of change in the firm's methods of production or rendering of services has either declined or accelerated.
- The rate of product/service introduction by the company relative to competitors has either declined or increased.

Proposition 1: Internal Uncertainty positively influences EMS development.

Section 2.4, highlights the topic of environmental systems and standards, which are both international in scope and relatively new. Therefore, a great deal of confusion and uncertainty surrounds the topic. External uncertainty consists of the concern over the rate of new product introduction in the industry, the rate of change in technology and the ability of the firm to accurately predict changing consumer needs for green products. Again, managers may be reluctant to pursue EMS development because the costs and the benefits have not been proven in their industry. Some managers may elect to wait until others have undergone green projects or EMS certification before proceeding, or until customers' demand it. Basically, there are many levels and sources of uncertainty impacting the motivations and extent of a firm's involvement in EMS.

Firms involved in industries with a high rate of change may be more reluctant to invest in new technology due to external pressures to allocate resources to constantly change. Additionally, short product life cycles bring about an explicit need for change at a fast rate, firms competing within this fast pace environment may not take on the development of a new information system such as an EMS. This will be especially true in firms that do not invest in scanning the marketplace for new "environmental" innovations. Other sources of external uncertainty involve the ability of the firm to predict changing consumer needs and the actions of competitors. In the fast paced industries of today's marketplace, firms may be allocating resources to better forecast consumer needs, manage inventory, and manage the supply chain (Fine 1998). Finally, in an environment where the actions of the competition are difficult to predict, developing or implementing an EMS may be a project that firms pursue only after other firms in the industry have demonstrated the benefits. Thus, external uncertainty has several unique traits impacting the development of an EMS.

The construct of "External Uncertainty" is measured by eight manifest variables that involve uncertainty about the speed or intensity of change in the firm's industry. The sources of external uncertainty include:

- The rate at which products/services are getting obsolete within the industry.
- The production/service technology is not subject to very much change and is well established.
- Demand and consumer tastes are fairly easy to forecast.
- Actions of competitors are quite easy to predict.
- The firm must rarely change its marketing to keep up with the market and competitors.

- The external environment poses a threat to the survival of your firm.
- The external environment is rich in investment and marketing opportunities.
- The external environment is easily controlled and manipulated.

Proposition 2: External Uncertainty negatively influences EMS development.

3.2.2 Firm Effect

As previously mentioned in section 2.5, the importance of a firm's resource capabilities and competitive advantage has been well-established in literature. The resource-based view of the firm posits that a competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). Therefore, the size of the firm and the amount of resources available to invest in an EMS are critical factors that influence the presence and development of a system. The size of the firm and resources available may also be dependent on the industry. Since certain industries have experienced greater environmental pressure than others, the analysis of an industry effect can guide, or direct future research efforts. Additionally, those firms selling their products in other countries and especially European countries may have external pressures to have a certified EMS from their customers. Section 2.7 highlighted many reasons for pursuing certification of an EMS and these same reasons justify the exploration of the impact of ownership, European trade, exporting, and the percentage of sales to the end customer. Finally, insights can be gained from analyzing and testing relationships between the size of the firm, amount of exporting and sales to end customers and the extent to which a firm has a well-developed EMS.

This construct "Firm Effect" consists of variables such as:

- Size of the firm

- Industry
- Ownership
- Amount of exporting to European countries
- Amount of exporting
- Sales to the end customer

Several hypotheses are generated from these measures:

Hypothesis 1: There is a positive relationship between the size of firms and the status of the EMS.

Hypothesis 2: The industry the firm is in will related to the status of the EMS and the chemical industry should have the most developed EMS.

Hypothesis 3: Type of ownership will be related to the status of the EMS.

Hypothesis 4: There is a positive relationship between the amount of European exporting and the status of the EMS.

Hypothesis 5: There is a positive relationship between the amount of exporting and the status of the EMS.

Hypothesis 6: The amount of sales to the end customer will have a positive relationship to the status of the EMS.

3.2.3 EMS Development

As was developed in Section 2.8, an EMS can be defined as:

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. This "environmental" information is primarily internally focused on pollution control and waste minimization. The use of this information for external stakeholders is primarily focused on the outputs of the firm and found in annual reports, or used to enhance firm image.

Development of the EMS construct consists of combining the definition and several manifest variables. Based on the information in Section 2.8, the relationship of this latent variable to other constructs is yet untested. The rest of this section examines the relationship of EMS development to other constructs in the conceptual model. Next, the EMS construct is developed.

Top management support and the sources of internal and external uncertainty will be determining factors for the development and integration of an EMS. Section 2.8 discusses attributes of a firm's commitment to EMS. These attributes can be identified in the following ways: (1) A senior corporate official has been assigned to implement the policy; (2) Lines of responsibility and accountability have been identified (e.g., environment is considered part of performance evaluation); (3) Goals have been defined that are measurable; and (4) Adequate resources have been allocated to implement the program. A related program element is whether the firm has developed systems to assist in measuring environmental performance, and the dissemination of information. These types of systems include monitoring systems that track the emission and discharges of pollution as well as the usage of raw materials, energy, and other inputs to production.

Even if a firm has developed superior environmental management tracking systems, ultimately, it is critical that these efforts lead to improvements in environmental performance. Firms must be able to demonstrate that they are making progress toward reducing pollutant generating releases and minimizing liability exposure. At a general level, producing data documenting waste generation, effluent discharges, spills of hazardous substances, and the like are both analytically tractable and, increasingly required by regulatory agencies and company stakeholders. The best firms in this regard set and achieve goals that are more stringent than those explicitly required by law.

When operationalizing the EMS construct, the objective is to develop a more comprehensive definition. A firm's commitment to an EMS will be a determining factor in the success of the system and the extent of the practices and benefits derived from environmental efforts. Environmental programs that include tracking, documentation, training, and reporting of environmental performance to all stakeholders become indicators of EMS development. Since this is a new construct, EMS development consists of nineteen manifest variables (see Appendix 1). The measures of this construct include:

- Existence of a formal EMS.
- The firm has a well developed environmental database for tracking and monitoring.
- Presence of a formal department responsible for environmental affairs.
- A formal reporting position between environmental affairs and senior executives.
- Top management has taken a highly visible public position is support of improved environmental performance.
- Formally documented EMS procedures.
- Procedures are widely circulated and available.
- Environmental information is tracked and monitored on an ongoing basis.
- Environmental performance is formally tracked and reported.
- Environmental performance is periodically captured and summarized.
- Performance goals have been developed which report performance on different levels.
- Environmental performance results are widely distributed within the company.
- Environmental position of the company is given prominent visibility in annual reports.
- Environmental achievements of your company are given prominent visibility within annual reports and other publications.
- Environmental issues, policies, and procedures are included in company training.
- People within the company consider the formal EMS highly effective.
- People outside the company consider the formal EMS highly effective.
- Attention is primarily focused on the underlying cause and corrective measures for environmental problems.
- When environmental problems are identified, the major effort in your company is determining the underlying reasons for that problem and taking action.

Proposition 3: EMS development is positively related to the environmental practices a firm considers.

3.2.4 Environmental Practices

As described in section 2.9, implementing an EMS requires a broad range of activities that include: (1)training to ensure that workers operate equipment and production processes correctly and are proactive with respect to addressing environmental risks; (2) new product design and development approaches (e.g., Design for Environment) that reduce the usage of raw materials, and lessen the generation of hazardous waste, by evaluating environmental risks throughout the product life cycle; and (3) monitoring to ensure that manufacturing operations are in compliance with pollutant emission standards and other regulatory requirements. As a result of this training, changes in product design, identification of environmental risks, and continual monitoring, firms will have several environmental practices available to them that may not have been present before the firm developed an EMS. Thus, there is a relationship between the status of the EMS and the extent of practices used by firms. These options will have significant impact on operations management and the way firms add value to a product.

The definition of EMS implies an integrated system. 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 1999). ERM is ultimately a cross-functional undertaking, and affects all of the functional areas of a business enterprise (Kleiner 1991; Post 1991; Williams 1991). It is here in the manufacturing process that firms set into place the actions that ultimately create the waste streams encountered in the transformation system. Operations Management determines what items will be produced, where, and in what quantities. These decisions, in turn, may cause the consumption of resources and the creation of waste (through the discarding of packaging, the operation of equipment and the types of material used). One way of controlling and reducing environmental waste streams is to make those responsible for production aware of the environmental impact of production schedules, and the associated costs.

The three latent variables representing the environmental practices a firm will consider are measured by fifteen manifest variables (see Appendix 1.). These constructs attempt to capture the importance of various options considered by a firm when facing waste and environmental issues. It is hypothesized that the more developed the status of the EMS the greater the options a firm will have to address environmental issues.

In the past, most of the research attention has been focused on product/process design (Fiksel 1996; Allenby 1993). This attention correctly recognizes the importance of product design to overall performance. After all, decisions made during this stage have a significant impact on environmental performance. For example, Fabrycky (1987) estimated that up to 85 percent of the life cycle costs are committed by the end of the preliminary design stages. In another study, Ulrich and Pearson (1993) found from a field research study that at least 50 percent of the costs (for a class of mature products) are design determined and that up to 70 percent of costs are affected by manufacturing process decisions. Overlooked for the most part has been the role of the EMS in the management of environmental design practice.

The construct "Design Practices" consists of:

- Process redesign: redesigning the process to eliminate any potential environmental problems.
- Product redesign: redesigning the product to eliminate any potential environmental problems.
- Reduce: reducing the level of material and/or components (which are contributing to environmental problems) within products.
- Substitution: replacing a materials which can cause environmental problems with another material which is not problematic.
- Returnable packaging: using packaging and pallets which can be returned after they are finished being used.

- Prolonged 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).
- Relocation: changing the location of a process or plant to take advantage of more favorable environmental regulations and conditions.
- Spreading risk: shifting responsibilities for environmental problems to a third party or expert better able to deal with issues.

Proposition 4: Design practices are positively related to firm performance.

Porter and Van der Linde (1995a) claim that companies must improve their ability to collect environmental cost and savings information. In most manufacturing systems, the people who do the planning of production are unaware of the impact of their plans on the level and timing of environmental waste. As a result, problems relating to production waste levels are often flagged by others operating outside of the manufacturing planning system. This often implies that plans previously generated through extensive work have to be revisited and revised, which is an extensive, time-consuming and often less than effective exercise. By integrating the manufacturing planning process with the waste management process, EMS can provide the manufacturing planner with the information needed to identify potential problems while still in the process of developing production plans. Given past experience with product design systems, such as simultaneous engineering, we know that early introduction of such issues results in better products being designed and developed in less time (Melnyk et al. 1996).

The construct "Manufacturing Practices" consists of:

- Remanufacturing: like rebuilding, except none of the parts are reduced to raw materials.
- Rebuilding: rebuilding a product where some of the parts or components are recovered while others are replaced.
- Disassembly: redesigning the product or process so as to simplify disassembly and disposal at the end of the product's life cycle.

- Recycle: Making more use of recycled components or making a product which is more easily/readily recycled.

Proposition 5: Manufacturing practices are positively related to firm performance.

At a minimum, any manufacturing firm should be in compliance with the appropriate governmental regulations. Often this compliance is attained by a series of short-term, reactive actions (Vastag, Kerekes and Rondinelli 1996). These reactive actions often put firms in the position to have to scramble and take actions aimed at bringing the situation back under control. In some cases, this means adopting the situation and paying the increased costs (due to fines or the purchase of pollution credits from other firms). In other cases, the schedule and/or the product mix may have been changed to something that will help bring down the waste levels. In some cases, the firm may even decide to shut down production until the problem is resolved. By understanding waste flows in advance with an EMS, the resulting flows of waste can be analyzed to determine whether or not they are in compliance and if alternative options are available to the firm.

In order for a firm to develop options for waste reduction, there needs to be an integrated system to make information available to the key people involved. Section 2.5 describes some of the benefits of an EMS and talks about a company's ability to accurately reflect the costs associated with current or proposed products and processes being the most critical information required in order for an ERM initiative to be given serious consideration (Sarkis and Rasheed 1995). Whenever a stream of waste is generated, there are a number of issues that must be resolved. It has been commonly accepted that there are great benefits to eliminating pollution at its source rather than reacting to the situation with end-of-pipe controls (Carpenter 1991). Capacity for waste management must be proactive and planned. This capacity consists of people who are trained in the handling, management and disposition of waste. It also consists of waste moving equipment and waste storage locations. A Green MRP system can provide the planner with the necessary tools to determine the schedule of waste and to formally plan the capacity necessary to manage this waste (Melnyk, Sroufe, Montabon, Calantone, Tummala, and Hinds 1999). This should result in better management of waste-related costs and, ultimately, a reduction in the overall level of overhead assigned to this area.

The construct "Waste Practices" consists of:

- Waste segregation
- Creating a market for waste products
- Alliances with suppliers or customers to address environmental problems
- Consuming the waste internally.

Proposition 6: Waste practices are positively related to firm performance.

3.2.5 Impact on Operations Performance

Section 2.10 of Chapter Two describe the potential impacts on performance for firms that develop an EMS. Many of these normative benefits describe waste reduction and better resource utilization. The approach taken in this dissertation is to view pollution (a waste product that consumes resources for its disposal), as equivalent to a high rate of defects, and by definition the result of faulty processes (Kleiner 1991). Having an EMS is believed to be one method of controlling conversion processes. With the control of conversion processes comes the opportunity to lower costs, improve quality, and reduce lead times. Tibor and Feldman (1996) claim that EMS certification can be found in situations where the firm expects to gain a competitive advantage through EMS certification.

There are many additional reasons why adopting an EMS should be attractive to firms e.g., increasing use of voluntary standards by their customers, the ability to reduce multiplicity/duplication (Litskas 1999), potential of ISO 14000 becoming a de facto requirement, government adoption, potential to reduce insurance rates, pollution prevention, and to help the firm achieve environmental excellence (Melnyk, et al., 1996).

In most cases a thorough strategic assessment of environmental issues will identify areas of weakness in the environmental management function, which can be addressed through targeted EMS development and improvement initiatives. These initiatives are, by their nature, firm and context specific. Often, these initiatives include an assessment and analysis phase and a development and improvement phase, the latter of which is focused on formulating missing elements (e.g., policies, procedures), integrating important EMS principles and tools, and establishing strategies for achieving desired patterns of internal and external information flow.

The construct “Firm Performance” consists of fourteen manifest variables. The variables include:

- Environmental activities have significantly improved quality
- Significantly reduced lead times
- Significantly reduced overall costs
- Benefits outweigh the costs
- Significantly improved position in marketplace
- Environmental activities within your firm have not adversely affected the position of your company in the marketplace
- Enhanced firm reputation
- Help design and develop better products
- Reduced waste within the production process
- Reduced waste within equipment selection process

- Environmental activities have caused the company to investigate alternative technologies and procedures
- Improved chances of selling product in international markets
- Have placed reasonable demands on information systems and data requirements
- Has not compromised the product's acceptance from the customers perspective

It is hypothesized that the more developed the EMS system, the more environmental practices a firm will be involved in, and the greater the positive impact on firm performance.

Proposition 7a: Firm performance is indirectly related to EMS through the environmental practices the firm is involved in.

Proposition 7b: Operations performance is directly related to EMS.

SUMMARY OF PROPOSITIONS AND HYPOTHESES

Proposition 1: Internal uncertainty positively influences EMS development.
Proposition 2: External uncertainty negatively influences EMS development.
Proposition 3: EMS development is positively related with the environmental practices a firm participates in.
Proposition 4: Design practices are positively related to firm performance.
Proposition 5: Manufacturing practices are positively related to firm performance.
Proposition 6: Waste practices are positively related to firm performance.
Proposition 7a: Firm performance is indirectly related to EMS through the environmental practices a firm is involved in.
Proposition 7b: Operations Performance is directly related to EMS.

Hypothesis 1: There is a positive relationship between the size of firms and the status of the EMS.
Hypothesis 2: The industry the firm is in will be related to the status of the EMS, and the chemical industry should have the most developed EMS.
Hypothesis 3: Type of ownership will be related to the status of the EMS.
Hypothesis 4: There is a positive relationship between the amount of European exporting and the status of the EMS.
Hypothesis 5: There is a positive relationship between the amount of exporting and the status of the EMS.
Hypothesis 6: The amount of sales to the end customer will have a positive relationship to the status of the EMS.

3.3 Research Design

Research design can be comprised of five major steps (Flynn et al. 1990; Creswell 1994); (1) identifying the theoretical foundation for the research; (2) selecting the appropriate design; (3) selecting the data collection method; (4) implementation; and (5) data analysis. Thus far, discussion has centered on defining research problem through the use of the literature, developing the model, operationalizing the constructs, identifying the manifest variables, and discussing the relationships between constructs in terms of propositions and hypotheses. Attention now turns to the research design, collection methods and data collection.

3.3.1 Survey and Field Study Design

The primary approach used in this dissertation is that of a large-scale survey complemented by field interviews at selected plants. The reason for the survey is to collect data that captures the attitudes of the respondents towards ERM, their environmental management system (EMS), and ISO 14000. The survey is also used to identify factors that influence these attitudes and the perceived effectiveness and efficiency of the plant environmental management systems. Field studies are used to substantiate the data from the survey and to validate non response bias.

The survey was developed and pre-tested by 15 respondents in a three-round process over a period of two months. This group represented a variety of positions and functions within their firms in a variety of industries. The pre-test group was asked to review the survey primarily for clarity of questions and time required to complete the survey. The primary potential problem with the survey that the pre-testers pointed out was concern over the length of the survey. The length of the survey is justified by the need to establish valid measures for the concepts that were included in the survey. There is very little previous work on which to base the questions on ERM, so it was decided to err on the side of length to ensure that valid measures were obtained. Concerns include awareness that any research concerning environmental issues was fraught with Socially Desirable Response (SDR) issues. To mitigate these issues, it is generally wise to include more questions as a validity check.

The survey consisted of 235 measurements grouped into five major sections. The first section gathered information about the respondent, their position, professional affiliations (if any), and extent of involvement in various initiatives (such as Just-in-Time or Lead Time Reduction programs). The second section focused on the business unit (the basic unit of analysis) and detail about it. This included product manufactured, extent of uncertainty facing the business unit and its personnel, and the status of various types of initiatives (e.g., Enterprise Resources Planning, Cross Functional Teams and QS 9000). Section III dealt with the perceived impact of the ISO/QS 9000 certification process on the business unit and its competitive position in the market place. In Section IV, the respondent was asked to evaluate a series of questions pertaining to ISO 14000. These questions assessed the level of knowledge of the respondent on the ISO 14000 certification process, as well as the factors affecting its implementation and use. The fifth and final section gathered information about the business unit's EMS, the effectiveness and efficiency of this system and the types of options used to improve performance.

3.3.2 Implementation and Data Collection

Three professional associations (National Association of Purchasing Management, American Production and Inventory Control Society and one group who wishes to remain anonymous) provided mailing lists of 5,000 names each. The constituency of each of the associations was different enough that very few of the names were found on more than one list. In addition, the researchers worked closely with a major American manufacturer, who provided an additional list of 104 managers. This secondary source resulted in 57 valid responses. In total, the researchers had a mailing list of 14,584 names, of which 1510 usable responses were received (a response rate of 10.35%). While this is lower that the 20% that researchers strive to achieve, the lower rate could be explained by the length of the survey (18 pages). With the focus on this dissertation on manufacturing firms, a sub-sample of 1331 respondents is used. The sub-sample response rates by wave are summarized in Table 3.1. The full sample information is available in Melny, Sroufe, Montabon, and Calantone (1999).

Table 3.1 Response Rates by Wave

Source of Respondents	1st Wave	2nd Wave	Unknown	Total
Anonymous Group	166	131	0	297
NAPM	258	186	0	444
APICS	395	184	0	579
Unknown	0	0	11	11
Total	819	501	11	1331

Before examining the results gained from this survey as they pertain to environmental systems, environmental performance, and corporate performance, an important first step is to examine the demographic characteristics of the sample. The examination of the sample will help establish the range of industries represented and how closely this matches the number of firms in the U.S in manufacturing industries. By establishing the traits of the respondents, this study can begin to assess the extent to which the results are generalizable, rather than an artifact of the specific composition of the sample from which the results are drawn.

3.3.3 Industrial Descriptive Information

One way of determining the extent to which the sample is representative is to evaluate the industrial settings from which the respondents were drawn. The respondents were asked to list the principal products produced in their plants. These responses (open-ended) were recoded into appropriate SIC (Standard Industrial Classification) codes by an external panel. For the purposes of this coding, a two-digit SIC code was used. The resulting distribution of industries is summarized in Table 3.2. The first section of the Table 3.2 identifies the manufacturing SICs used in the data analysis. With the focus of this dissertation on primarily manufacturing plants, the first half of Table 3.2 is used in the data analysis in Chapter 4.

Table 3.2 Classification of Respondents by 2-Digit Standard Industry Code (SIC)

SIC Description	Frequency (#)	Percent (%)
Industrial & Commercial Machinery & Computer Equipment (35)	316	23.7
Fabricated Metal Products, Except Machinery & Transportation Equipment (34)	179	13.4
Electronic & Other Electrical Equipment & Components Except Computer Equipment (36)	179	13.4
Transportation Equipment (37)	141	10.6
Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks (38)	127	9.5
Chemicals & Allied Products (28)	99	7.7
Industry Not Identified	53	4.0
Primary Metal Industries (33)	38	2.9
Furniture & Fixtures (25)	35	2.6
Rubber & Miscellaneous Plastic Products (30)	34	2.6
Paper & Allied Products (26)	27	2.0
Business Services (73)	27	2.0
Miscellaneous manufacturing Industries (39)	22	1.7
Petroleum Refining & Related Industries (29)	18	1.4
Textile Mill Products (22)	16	1.2
Stone, Clay, Glass, & Concrete Products (32)	16	1.2
Leather & Leather Products (31)	4	0.3
Totals	1331	100.0

As can be seen from this table, the respondents came from a wide range of industries. From the 16 SIC codes, the bulk of respondents (942 respondents or 70% of the respondents) were drawn from one of five SIC codes:

- Industrial & Commercial Machinery & Computer Equipment (35): 316 respondents.
- Electronic & Other Electrical Equipment & Components Except Computer Equipment (36): 179 respondents.
- Fabricated Metal Products, Except Machinery & Transportation Equipment (34): 179 respondents.
- Transportation Equipment (37): 141 respondents.
- Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks (38): 127 respondents.

To an extent, it can be argued that the concentration of the respondents from these five sectors is consistent with the industrial activities within the United States. In addition, these five industries are ones that should be interested in ERM-oriented activities within their firms. Other indicators of the diversity from the survey data include the median number of Full Time Equivalent Employees, a proxy for plant size (400), percentage of export sales (19.7%), percent of sales to the European Community (9.7%), and the average percentage of sales going to the end customer (24.6%). Furthermore, 729 plants (48.3%) were publicly owned, 250 (16.6%) were foreign-owned, and 54 plants (3.6%) were joint ventures.

3.3.4 Background of the Respondents

Having reviewed the industries and firms from which the respondents came, the next step is to determine the nature of the respondents themselves. A starting point is to focus on the job titles of the respondents. As can be seen from Table 3.3, the respondents embody variety in terms of their job titles. They occupy positions ranging from presidents and Chief Executive Officers (CEOs) to managers and staff. This diversity argues strongly in favor of the generalizability of the results.

Table 3.3 Stated Positions of the Respondents

Stated Position	Frequency (# Observations)	Percentage (%)
Chief Executive Officer	11	0.8
President	12	0.9
Vice-President	147	11.0
Manager	629	47.3
Senior Management	226	17.0
Staff	277	20.8
Not Listed	29	2.1
Total	1331	100.0

The next piece of information important to this study is that of the length of time that the respondents had been spent in their current position. Overall, the respondents were not new to their positions. On average, the respondents had been in their current positions for about 5.4 years. As a result, we can expect that these respondents should be familiar with their jobs and what is happening around them. In addition, data on the functional areas in which the respondents worked was also collected. This data is summarized Table 3.4. The two major areas represented in the survey data were materials purchasing and manufacturing. Of interest, environmental management (compliance) represented a very minor part of the data at 48 respondents (3.2 % of the respondents). This indicated that this survey consists primarily of users (engineers, purchasing managers and manufacturing people) who should be better able to assess ERM as business/strategic decisions. Again, this was consistent with the objectives of this study.

Table 3.4 Respondents Classified by Functional Area

Functional Area	**Number of Respondents**	**Percentage**
Purchasing, Materials	572	43%
Manufacturing/Production	296	22.2
Quality	123	9.2
Engineering	81	6.1
Environmental (Compliance)	40	3.0
Management	38	2.9
Other	34	2.6
Distribution	29	2.2
Unknown/not identified	29	2.2
Information Systems	28	2.1
Safety, Security	17	1.3
Inventory	13	1.0
Marketing	12	0.9
Consulting	09	0.7
Human Resources	3	0.2
Research and Development	3	0.2
Accounting	2	0.2
Finance	2	0.2
Total	1331	100.0

Based on these findings, we can argue that the survey data embodies a representative sample of the general population. Further, based on these traits, the results drawn from this survey should be representative and, therefore, generalizable.

3.3.5 Field Studies

The purpose the field visits was to identify the ways in which EMSs and certification are adopted and implemented by a variety of firms. Since the focus of this research was exploratory in nature, qualitative data collection methods were used. Field-based data collection methods were used to ensure that the important variables were captured during the interview process. These methods also helped develop an understanding of why these issues/variables might be important Eisenhardt, (1989). A small detailed sample fit the needs of the research and complimented the large-scale survey. The method followed was similar to the grounded theory development methodology suggested by Glasser and Strauss (1967). In addition, suggestions made by Eisenhardt (1989) regarding case studies, Miles and Huberman (1994) regarding qualitative data analysis, and Yin (1994) were incorporated.

In instances where there does not exist a well developed set of theories regarding a particular branch of knowledge, Eisenhardt (1989) and McCutcheon and Meridith (1993) suggest that theory-building can best be done through case study research. The case-based process involves defining the question, selecting cases, crafting instruments and protocols, analyzing data, shaping hypothesis, enfolding the literature and reaching closure using an relatively small group of research sites. Comparative literature reviews of research on environmental management systems confirm that this area is at an early stage development (Klassen 1995; Klassen and Whybark 1995; Porter and van der Linde 1995b). In this stage of theory building, a key objective is to characterize the different types of firms involved in EMS implementation and those firms not involved in EMS implementation, or certification.

There are some pitfalls of case study analysis, including lack of simplicity or narrow and idiosyncratic theories (Eisenhardt 1989, 1991). A primary disadvantage of the case research approach is that it is difficult to draw deterministic inferences, and there are limitations in terms of the external validity of the study. These limitations are often addressed by the using large sample studies, or using "before" and "after" quasi-experimental designs (Cook and Campbell 1979). However, given the current stage of theory building on ISO 14000, it is important to ensure that the right questions regarding the differences in firms participating in Environmental Management System (EMS) certification. Eisenhardt, (1989) recommends that the researcher develop a set of initial research questions that posit linkages between proposed key constructs. As the analysis proceeds, the questions can be modified and refined, so that future studies will be properly directed. While causality can never be shown in case studies, analysis of data collected from multiple sites can help support the development of theory and the generalizability of the results.

The researchers participating in this project, relied primarily on the methods of qualitative data analysis developed by Miles and Huberman (1994), which consists of anticipatory conceptual model development and simultaneous data collection, reduction, display, and conclusions testing. Multiple research sites were used in order to provide a broader understanding of EMS development within firms and the reasons for firms to choose EMS certification.

3.3.6 The Sample

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

The researchers initially set out to find a set of plants at different stages of integration with regard to EMSs and ISO 14000 certification. Firms from different EMS stages, industries (i.e. pharmaceutical, furniture, and automotive tier-one suppliers), products, processes and size of the firm were selected based geographic proximity and knowledge of the researchers. Each of the firms selected was chosen to represent a spectrum of EMS status. The objective of this sampling approach was to construct a sample of firms that would be diverse enough to capture the EMS attributes available across firms that may be overlooked in a single industry or product sample and to confirm findings from the large scale survey.

Through the use of information from a Total Quality Environmental Management survey by Curkovic, (1998) and the researchers' experience with different companies, a list of potential companies was developed. In most cases environmental and operations managers were contacted at the divisional level. An initial idea of the level of EMS understanding and implementation was determined through preliminary screening over the telephone. Next, site visits, and follow up phone calls were used to collect data on the eight companies reported within this chapter.

After the initial screening, which also assessed the willingness of the company to participate in the study, site visits were arranged. The interviews were conducted with managers responsible for the EMS strategy at each site using the structured interview protocols presented in (Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe, and Montabon 1999).

3.3.7 The Interview Protocol

Eisenhardt (1989) suggested that a researcher should have a well-developed interview protocol before making site visits. A structured interview protocol was used at all of the site visits. After each visit, the protocol was reviewed, and/or updated to accommodate new lessons learned. This constant updating of the protocol after each visit is a foundation of grounded theory development Glasser and Strauss (1967). Eisenhardt (1989) suggested that data collection and data analysis should be done simultaneously. In other words, the data from one case is collected and then analyzed before the next replication is performed. Improvements in the protocol can be made between replications by collecting data in this manner. Important issues that are raised in early cases can be included in the protocol for subsequent replications. This ability to refine and improve upon the protocol between cases is a significant advantage of this type of qualitative research. For the sake of clear explanation the data collection and analysis are described in the following sections. However, the actual process was one where a case was collected, analyzed, and if needed, the protocol was improved upon, and then data from the next case was collected.

There are differing opinions as to the amount of prior instrumentation required before conducting site visits for qualitative research (Miles and Huberman 1994). Some prior instrumentation was appropriate for this conceptual model proposed in the introduction. The interview protocol included in Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe, and Montabon (1999), was developed based on the researchers' general understanding of ERM issues facing industry today. The protocol was pre-tested at two manufacturing facilities and then used for the eight firms included in this study.

The researchers carried out the interviews in the respondent's facilities. The discussion generally progressed serially through the interview protocol. The general context of the firm and the respondents were first discussed. These contexts involved the size of the firm, competitive thrusts, and key success factors. The discussion was then turned to the type of EMS system in place, factors influencing the decisions surrounding EMS, and, environmental performance measures. For summaries see Appendix 3.

3.3.8 General Respondent Information

Respondents were first identified from a list of respondents from a previous Total Quality Environmental Management survey (Curkovic, 1998). The title and the (number of years in current position) are as follows:

- Firm F: Manager, Health, Safety, & Environmental Quality (1 year in current position)
- Firm H: Manager of Environmental Systems (5yrs, 25 environmental)
- Firm G: Corporate Manager of Safety and Environmental Strategies (26 years) and the Operations Management Manager for the nearest facility (2 years)
- Firm A: Environmental Engineer (7yrs)
- Firm C: Corporate Environmental Manager (6years)
- Firm E: Manager of Technical Services "Quality and Environmental Manager" (13 years)
- Firm D: Manager "Leader" Environment and Safety (16 yrs)
- Firm B: Operations Manager (4 years)

3.4 Unit of Analysis

The unit of analysis for empirical validation is the plant level. The plant is the level of implementation for most EMSs and is used most frequently in the Operations Management literature.

3.5 Research Methodology

The four principal research methods now employed by social researchers are fieldwork, survey research, experimentation, and non-reactive research. A major source of uncertainty is that any study employing a single type of research method leaves untested rival hypotheses (or alternative hypotheses of the data) that call the validity of the study's findings into question (Brewer and Hunter 1989). Many of the rival hypotheses defy testing because they are beyond our current practical, theoretical, or methodological capabilities. A good many other merely elude testing. They elude testing for two reasons, either because the particular method employed fails to provide the data needed to test them or because they stem from possible biases inherent in the study's single method. Each type of method, considered alone, is imperfect in this respect. The proposed research combines qualitative fieldwork with quantitative survey research.

According to Brewer and Hunter (1989), the growing knowledge of the individual weakness of social sciences methods has led many researchers to an interesting conclusion: social science methods should not be treated as mutually exclusive alternatives among which we must choose and then passively pay the costs of our choices. Our individual methods may be flawed, but fortunately the flaws in each are not identical. A diversity of imperfection allows us to combine methods not only to gain their individual strengths, but also to compensate for their particular faults and limitations. The multimethod approach is largely built upon this insight. Its fundamental strategy of the multimethod approach is to attack a research problem with an arsenal of methods that have non-overlapping weaknesses in addition to their complementary strengths.

The reasons for using a single method or paradigm "qualitative, or quantitative" according to Creswell (1994), are pragmatic, such as the extensive time required to use both paradigms adequately, the expertise needed by the researcher, the desire to limit the scope of the study. Fortunately, the data collection has already been done for the proposed research. The multimethod, or "triangulation" Denzin (1978) approach is based on the assumption that any bias inherent in particular data sources, investigators, and methods would be neutralized when used in conjunction with other data sources, investigators and methods (Jick 1979).

Reasons for combining methods in a single study include:

- Any study employing a single method leaves untested rival hypotheses that question the studies validity.
- The flaws of individual methods are not the same, by combining methods we allow for the weaknesses while combining the strengths
- What results is the convergence of results and complimentary findings.
- It is complimentary in that overlapping and different facets of a phenomenon may emerge.
- This approach is developmental in that the first method is used sequentially to help inform the second method.
- Mixed methods add scope and breadth to the study.

There are three stages to the proposed research methodology:

1. Building the measurement model
2. Building the SEM model
3. Regression and univariate analysis of variance

During the first stage of development, the measurement model will be tested using confirmatory factor analysis (CFA) before testing the structural equation model (SEM) shown in Figure 1.1. This procedure helps to ensure that the constructs are unidimensional and valid before testing the relationships between all constructs in the full SEM (Bryne 1994). A priori theoretical relationships are the basis for the hypothesized model and CFA will be used to further refine and validate scales. This procedure will test the factors for internal reliability, or unidimensionality. The purpose is to ensure unidimensionality of multi-item constructs and to eliminate unreliable items. After elimination of cross-loading items, and items that have low item to construct loadings, comparative fit index (CFI) will be assessed to indicate if a good fit of the CFA model to the data exists and RMSEA.

The test of the SEM constitutes a confirmatory assessment of nomological validity (Cronbach and Meehl 1955). Omitted variables may bias the results of the SEM and provide a threat to the validity of the results. To help insure such specification errors are not influencing the results the theta delta matrix will be tested for bias, and the results of the SEM will be reviewed for nomological validity.

The relationship among the firm effect variables and EMS development will be explored using regression analysis and univariate analysis of variance to develop a better understanding of what firm attributes significantly impact EMS. This same analysis will also be performed between sets of measures of environmental practices and firm performance. Through the results of regression and analysis of variance, an explanation can be developed as to what firm effect variables impact EMS development.

3.6 Limitations of the Research

- Survey based research criticisms/limitations
- The topic of environmental management systems and ERM in general is in the early stages of development.
- SEM techniques allow correlation between variables to be controlled for, and allow for measurement error (Bollen 1989). The limitation of this methodology is that it can only serve to disconfirm a model, not prove it (Handfield and Ghosh 1997). Basically, the conceptual model in figure 1.1 is designed to only test whether the theoretical model can be rejected.
- Environmental topics have a high degree of social desirability. That is, respondents may answer questions in a way that portrays a "good" environmental image.
- The survey is a snapshot in time, 1997.

3.7 Summary: Chapter Three

This chapter builds on the theoretical foundation developed in Chapters One and Two. With a conceptual model developed, arguments for the propositions and hypotheses between the constructs in Figure 1.1 are presented. The summated scales for the new constructs in the conceptual model are developed using many untested manifest variables. Further discussion is then focused on the selection of the research design and data collection methods. Descriptive statistics of the respondents to the survey instrument are presented. Additional information is also presented on the respondents of the field studies. Next, discussion turns to the unit of analysis at the plant level. Finally, the proposed methods of analysis are discussed. Chapter Four will next discuss the analysis of the data.

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

Chapter Four contains the data analysis and results prescribed in the previous chapter. This chapter begins with a brief discussion of communicating Structural Equations Modeling (SEM) results through the use of a path model. The next section discusses the two-phased process where a conceptual model is first developed and validated using Confirmatory Factor Analysis (CFA) on a measurement model. Sections 4.3 and 4.4 discuss the data used in the structural equation analysis and measurement model results. Sections 4.5 discusses the measurement model results while highlighting cross validation, non-response bias, and the goodness of fit results as a lead in to section six. Next, the measurement model is tested in the second stage when the full structural equation model (SEM) is estimated. Section 4.6 highlights the full SEM while Section 4.7 discusses common methods bias and omitted variable bias.

The SEM involves relationships among latent variables, and concern during the first phase involves testing the extent to which these relationships are valid. It is critical that the measurement of each latent variable is psychometrically sound. The basis for this staged approach is that an accurate representation of the reliability of the observed or manifest variables is accomplished in two stages to avoid interaction of the measurement model and overall SEM model (Hair et. al. 1984). Finally, Section 4.8 is a summary of the analysis findings and Section 4.9 is a summary of the field studies carried out at eight manufacturing facilities.

4.2 SEM Communication

Because of the large amount of statistical information that emerges from analysis of structural equation models and the variability in what portion of that information investigators include in their reports. Informative and complete communication of SEM results is a challenging but essential aspect of the SEM approach. A primary form of communicating SEM hypotheses and results is the path diagram. The most informative path diagram includes an indication of all parameters in the model.

An additional issue associated with the use of path diagrams concerns precisely what the diagram should depict (Biddle and Marlin 1987). The path diagram can depict information in the following ways:

1. The model originally specified and estimated by the investigator.
2. That portion of the original model for which parameter estimates were significant.
3. A model that resulted from one or more modifications and reestimations of the original model.

The model shown in Figure 4.1 (in EQS notation) is the SEM model resulting from modifications and reestimations from the conceptual model (Figure 4.2) discussed in Chapter Three. Figure 4.1 represents a typical covariance model and can therefore be decomposed into submodels representing the measurement and structural equation models.

FIGURE 4.1. STRUCTURAL EQUATION MODEL

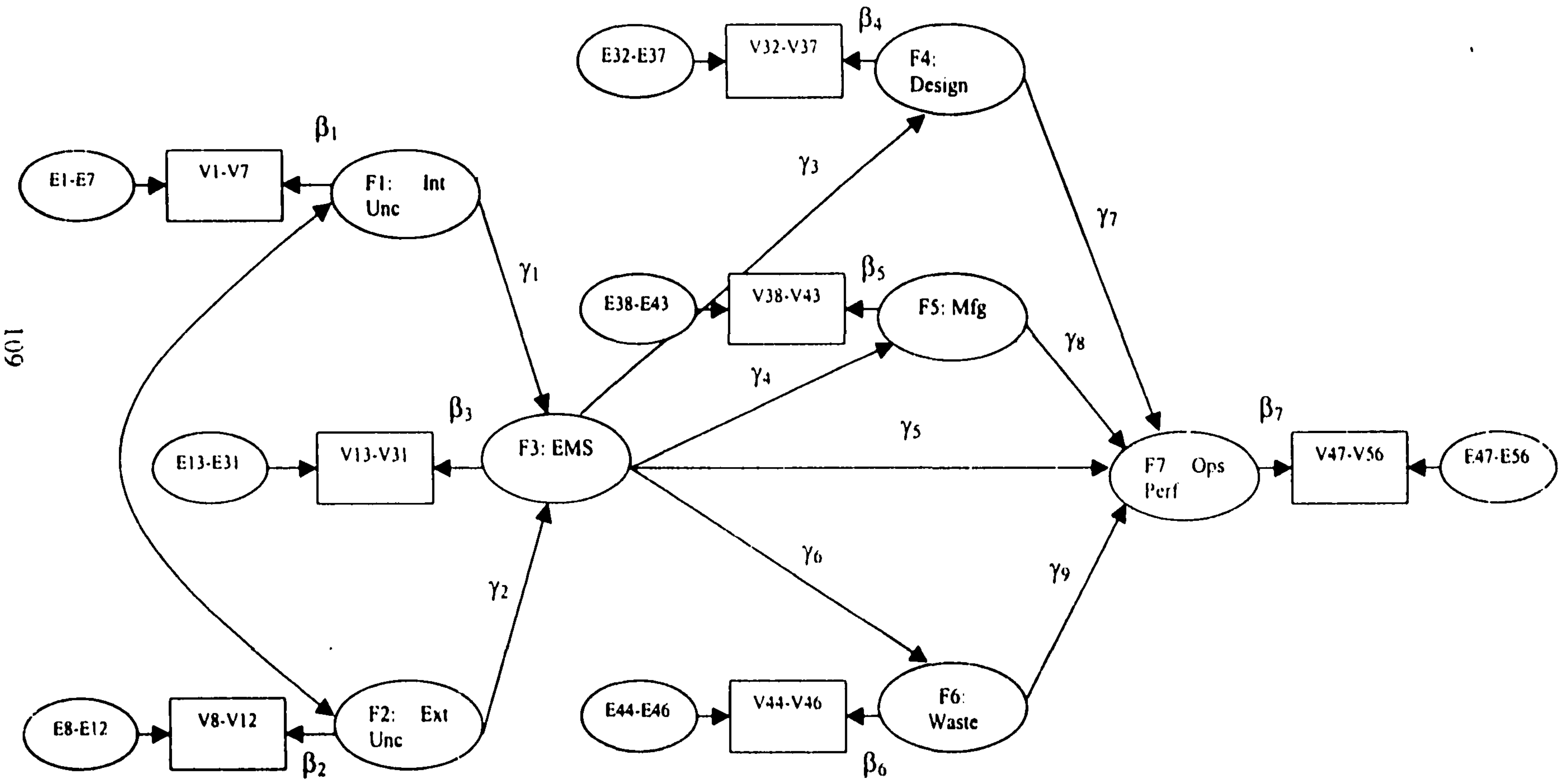
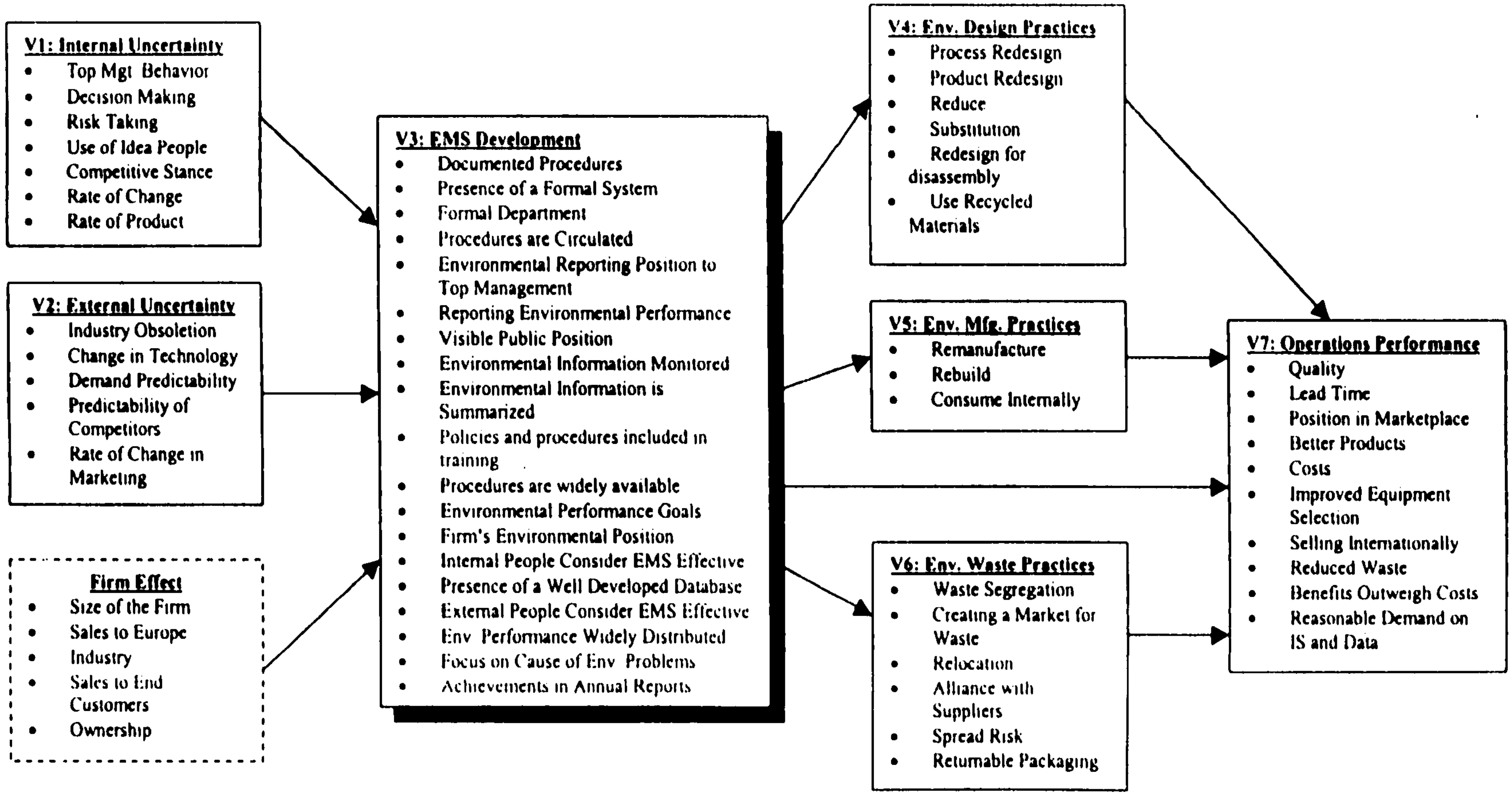


FIGURE 4.2 CONCEPTUAL MODEL



- **Bullets represent measures for each latent construct**

4.2.3 Two Stage Analysis

Many researchers (Kenny 1979; Williams and Hazer 1986; Gerbing and Anderson1988) are now proposing 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 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. When faced with measures that are less reliable, or theory that is only tentative, the researcher should consider a staged approach to maximize the interpretability of both measurement and structural models.

The measurement model helps to define relations between observed variables and unobserved constructs. This phase of model building provides the link between item scores in the measurement instrument and the factors they were designed to measure. The measurement model specifies the way in which each item loads onto a given factor. The submodels of the measurement model are found in the rectangles representing a manifest variable.

The measurement model hypothesizes *a priori* that the model can be conceptualized in terms of seven factors; each of the observable variables will have a nonzero loading on the factor it was designed to measure, and zero loadings on all other factors. Additionally, the measurement model assumes that the error terms associated with each observed variable are uncorrelated.

Once the model has been specified, the next task is to obtain estimates of the free parameters from a set of observed data. Although single stage least squares methods such as those used in ANOVA or multiple regression designs can be used to derive parameter estimates, iterative methods such as maximum likelihood or generalized least squares are preferred (Hoyle 1995). These iterative methods involve a series of attempts to obtain estimates of free parameters that imply a covariance matrix resembling the observed matrix. The implied covariance matrix is the covariance matrix that would result if values of fixed parameters and estimates of free parameters were substituted into the structural equation, and then used to derive a covariance matrix. Iteration begins with a set of start values, tentative values of free parameters from which an implied covariance matrix can be computed and compared to the observed covariance matrix. Start values are either supplied by the researcher, or are supplied by the computer software.

After each iteration, the resulting implied covariance matrix is compared to the observed matrix. The comparison between the implied and observed covariance matrices results in a residual matrix. The residual matrix contains elements whose values are the differences between corresponding values in the implied and observed matrices. Iteration continues until it is not possible to update the parameter estimates and produce an implied covariance matrix whose elements are any closer in magnitude and direction to the corresponding elements in the observed covariance matrix. Basically, iteration continues until the values of the elements of the residual matrix cannot be minimized any further. At this point the estimation procedure is said to have converged.

When the estimation procedure has converged on a solution, a single number is produced that summarizes the degree of correspondence between the implied and observed covariance matrices. This fitting function approaches zero as the implied covariance matrix more closely resembles the observed covariance matrix. A perfect match between the two matrices produces a value of fitting function equal to zero. The value of the fitting function is the starting point for constructing indexes of model fit.

4.3 The Data

As discussed in Chapter Three, Section 3.2, a two-wave mailing with reminder postcards sent between mailings (Dillman 1978) resulted in the return of 1510 usable surveys from the first and second wave of responses. The sample was targeted across two-digit Standard Industry Codes (SIC) 20 through 39 for United States Manufacturing firms. After elimination of nonmanufacturing SIC codes and unknown respondents, a sample size of 1320 was obtained. The unit of analysis was the individual plant. See Chapter Three, Section 3.2 for more information regarding data collection. Descriptive statistics of the survey respondents for the first and second waves of respondents are provided in Table 4.1.

Table 4.1 Group 1: First Wave Respondents (n=819)

	N	Mean	Median	Std. Dev.
Respondent's Experience				
In current position (years)	803	3-5yrs (3.22)	3.0	1.34
Public Ownership	373	.46	NA	.50
Foreign Ownership	158	.19	NA	.39
Private Ownership	331	.40	NA	.49
Joint Ownership	24	.029	NA	.17
Annual Sales	729	1,140,435.2	80,000	4,429,024.48

Group 2: Second Wave Respondents (n=501)

	N	Mean	Median	Std. Dev.
Respondent's Experience				
In current position (years)	496	3-5yrs (3.32)	3.00	1.36
Public Ownership	245	.46	NA	.50
Foreign Ownership	76	.19	NA	.36
Private Ownership	199	.40	NA	.49
Joint Ownership	24	.029	NA	.21
Annual Sales	437	663,644.21	70,000	2,251,400.60

4.4 Assessment of Measurement Model Fit

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

The most widely used statistic for assessing overall fit is the chi-square statistic. The probability level associated with the chi-square gives the probability of attaining a large chi-square given the hypothesized model is supported. A nonsignificant statistic indicates the covariance matrix of the proposed model does not differ significantly from the observed covariance matrix. Other indices of fit include the Normed (NFI) and Nonnormed Fit Indices (NNFI) (Bentler and Bonett 1980), and the Comparative Fit Index (CFI) (Bentler 1990). Bentler recommends the CFI as the index of choice. Values of the NFI and CFI range from 0 to 1 and are derived from the comparison of a hypothesized model with the independence model. Each provides a measure of complete covariation in the data, with a value greater 0.90 indicating an acceptable fit to the data. The use of multiple fit criteria, or triangulation is a good approach to assessing fit. (Jick 1979).

4.4.1 Identification

In determining if the measurement model is identified, the number of parameters to be estimated must be summated. In the proposed model there were 64 factor loadings, 64 measurement error variances totaling 128. Given the 64 observed measures in the model, there are 2080 pieces of information in the sample covariance matrix (64 * (64+1) /2) = 2080. Thus, the model is identified with 1952 degrees of freedom.

4.4.2 Treatment of Nonnormality

One assumption of structural equation modeling is that the data are multivariate normal. Since raw data was used as input, EQS provides univariate as well as several multvariate sample statistics. Turning first to the univariate statistics, such as the mean, standard deviation, skewness, and kurtosis, the data appears to be in order. The items were not found to be severely kurtotic, with only one variable having a skewness value of greater than 2. This variable was dropped from the final CFA model. Values of skewness ranged from -1.0165 to 0.5217. Values of kurtosis ranged from -1.3764 to 1.0852. When variables demonstrate significant non-zero univariate kurtosis, it is certain that they will not be multivariate normally distributed. After preliminary assessment and subsequent elimination, none of the remaining variables in the final CFA had indications of departures from normality (e.g. skewness $\geq$ 2, kurtosis $\geq$ 7; (Bentler and Chou 1987)).

The multivariate statistics reported in EQS output represent variants of Mardia's (1970) coefficient of multivariate kurtosis (Table 4.2). Although there is no absolute determinant of the extent to which a sample can be considered nonnormal, Bentler suggests large values of the normalized coefficient do indicate kurtosis (Bentler 1989;

1995). Thus, the Mardia's Coefficient of 156.5662, is strong evidence of multivariate nonnormality (Bentler, 1995).

To date, the most widely used fitting function is for structural equation modeling is the Maximum Likelihood (ML) function (Bollen 1989). The estimation of parameters in the model was first done using ML estimation. Due to nonormality indicators, specifically the Mardia's coefficient, Elliptical Reweighted Least Squares (ERLS) was also used for estimation (Sharma, Durvasula and Dillon 1989).

Table 4.2 Multivariate Kurtosis CFA Model

MARDIA'S COEFFICIENT (G2,P) =	763.3805
NORMALIZED ESTIMATE =	156.5662
ELLIPTICAL THEORY KURTOSIS ESTIMATES	
MARDIA-BASED KAPPA =	0.2350
MEAN SCALED UNIVARIATE KURTOSIS =	-0.2859

EQS also attempts to identify multivariate outliers. The program output automatically lists the five cases contributing the variables having the largest impact on the multivariate kurtosis coefficient. There is no absolute value upon which to define an outlier and it is possible that none of the five cases is actually an outlier. The impact of a potential outlier can be determined by model analysis both with and without the case included. A comparison of the results was then made to examine the five cases. Since the results were comparable, none of the cases were omitted.

4.4.3 Testing the Hypothesized Measurement Model

In many applications theory can provide only a starting point for the development of a theoretically justified model that can be empirically supported. Thus, the analyst must employ SEM not just to empirically test the model, but also to provide insights into its respecification. One note of caution must be made. The researcher must be careful not to employ this strategy to the extent that the final model has acceptable fit but is not generalizable to other samples or populations. The respecification of a model must always be made with theoretical support rather than just empirical justification.

The measurement model is a submodel in structural equation modeling that specifies the indicators for each construct, and assesses the reliability of each construct for estimating the causal relationships. The measurement model is similar in form to factor analysis; the major difference lies in the degree of control provided the researcher. In factor analysis, the researcher can specify only the number of factors, but all the variables have loadings. In the measurement model, the researcher specifies which variables are indicators of each construct, with variables having no loadings other than those on its specific construct.

Initial testing of the hypothesized model yielded relatively high fit indices (i.e., in the .80 + range) and a high chi-square to degrees of freedom ratio (i.e., greater than 6.0). 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).

Based on the information in Chapters two and Three, 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. Three of the constructs remained as predicted with four constructs experiencing minor changes through the elimination and reorganization of measures. Appendix 2 lists the constructs and measures used for the final CFA model (within Appendix 2, those measures dropped from the final measurement model are bulleted using ⇏). Instead of presenting the measurement model output and the several tables associated with the results, a summary of the results are as follows:

- Internal uncertainty retained all measures.
- External uncertainty dropped three measures (Plsit1, Plsit2 and Cosit) due to low parameter estimates.
- EMS development retained all nineteen measures.
- Design practices dropped Optrepck, and Optspred due to cross loadings with waste practices, while Optproln, Optreloc, were dropped due to cross loadings with manufacturing practices. Optdis and Optrecycle were added to the design practices construct after cross loadings were found in manufacturing practices.
- Waste practices dropped Optconsm due to cross loading with manufacturing practices and added Optrepck and Optspread from the design practices construct.
- Manufacturing practices dropped one measure due to high kurtosis and added the Optconsm measure from Waste Practices.
- Operations Performance dropped four measures (Actadvrs, Actrep, Actalt, and Actaccpt) due to low factor loadings.

After dropping or reassigning measures to the CFA model, the final measurement model was run using both ML and ERLS estimation. The results from testing the final measurement model are displayed in Table 4.3.

Table 4.3 Goodness-of-fit Indices for the Final CFA Model

MAXIMUM LIKELIHOOD SOLUTION (NORMAL DISTRIBUTION THEORY)

CHI-SQUARE = 10069.661 BASED ON 1463 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001

BENTLER-BONETT NORMED FIT INDEX=	0.812
BENTLER-BONETT NONNORMED FIT INDEX=	0.826
COMPARATIVE FIT INDEX (CFI) =	0.834
STANDARDIZED RMR =	0.053

ITERATIVE SUMMARY

ITERATION	PARAMETER ABS CHANGE	ALPHA	FUNCTION
1	3.195164	0.50000	18.33581
2	1.232256	1.00000	9.35552
3	0.055055	1.00000	9.23056
4	0.017107	1.00000	9.22262
5	0.006253	1.00000	9.22150
6	0.002188	1.00000	9.22133
7	0.000926	1.00000	9.22130

ITERATIVELY REWEIGHTED GENERALIZED LEAST SQUARES SOLUTION
(ELLIPTICAL DISTRIBUTION THEORY)

CHI-SQUARE = 9204.375 BASED ON 1463 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001

BENTLER-BONETT NORMED FIT INDEX=	0.959
BENTLER-BONETT NONNORMED FIT INDEX=	0.963
COMPARATIVE FIT INDEX (CFI) =	0.965
STANDARDIZED RMR =	0.053

ITERATIVE SUMMARY

ITERATION	PARAMETER ABS CHANGE	ALPHA	FUNCTION
1	0.000333	1.00000	8.42892

The iterative summaries for the measurement model are included in Table 4.5 to show a synopsis of the number of iterations required for a convergent solution and the mean absolute change in parameter estimates associated with each iteration. Typically, one would like to see the need for only a few iterations where the change in parameter estimation stabilizes after the first couple iterations. As shown in Table 4.5, convergence was relatively quick with only seven, and one iteration respectively for ML and ERLS estimation.

4.4.4 Evaluation of Fit

A model is said to fit the observed data to the extent that the covariance matrix it implies is equivalent to the observed covariance matrix (i.e., the elements of the residual matrix are near zero). The question of fit is a statistical one that must take into account features of the data, the model, and the estimation method.

The most common index of fit is the χ^2 goodness-of-fit test, which is derived directly from the value of the fitting function. That product is distributed as χ^2 if the data are multivariate normal and the specified model is correct. After modification of the measurement model described in section 4.5.3, the final measurement model yielded a $\chi^2_{(1463)}$ = 9304.375 and a CFI = .965. The goodness of fit indices indicated a well-fitting model.

4.4.5 Interpretation

If either the χ^2 goodness-of-fit test or adjunct fit indexes indicate acceptable overall fit of a specified model, then the focus moves to specific elements of fit. Individual estimates of free parameters are evaluated according to their difference from some specified null value, typically zero. The ratio of each estimate to its standards error is distributed as a Z statistic and, therefore, must exceed 1.96 before the estimate can be considered reliably different from zero.

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 s fitted the data well. First, to make certain that a given item represented the construct underlying each factor, a loading of 0.50 was used as the minimum cutoff. The standardized solution of the measurement model with factor loadings and R-squared are given in Table 4.4.

Table 4.4 Standardized Solution

STANDARDIZED SOLUTION:	R-SQUARED
COBEHAV =V1 = .820*F1 + .572 E1	.673
COPOSTUR=V2 = .750*F1 + .661 E2	.563
PLRISK =V3 = .671*F1 + .741	.451
PLIDEA =V4 = .647*F1 + .763 E4	.418
PLCOMP =V5 = .627*F1 + .779 E5	.393
PLCHANGE=V6 = .536*F1 + .844 E6	.287
CONEW =V7 = .543*F1 + .840 E7	.295
COOBSO =V8 = .712*F2 + .702 E8	.507
COTECH =V9 = .689*F2 + .724 E9	.475
COTASTES=V10 = .568*F2 + .823 E10	.323
COPROD =V11 = .638*F2 + .770 E11	.407
COMARK =V12 = .640*F2 + .769 E12	.409

EMSDOC =V13 = .856*F3 + .516 E13	.733
EMSFORML=V14 = .844*F3 + .537 E14	.712
EMSDEPT =V15 = .781*F3 + .624 E15	.610
EMSCIRC =V16 = .823*F3 + .568 E16	.677
EMSRPT =V17 = .796*F3 + .605 E17	.633
EMSEPERF=V18 = .915*F3 + .403 E18	.837
EMSVIS =V19 = .850*F3 + .527 E19	.722
EMSEINF =V20 = .849*F3 + .529 E20	.720
EMSSUMM =V21 = .909*F3 + .416 E21	.827
EMSTRAIN=V22 = .842*F3 + .539 E22	.709
EMSGOALS=V23 = .916*F3 + .401 E23	.840
EMSPOS =V24 = .838*F3 + .545 E24	.703
EMSINEFF=V25 = .845*F3 + .535 E25	.714
EMSDATA =V26 = .853*F3 + .521 E26	.728
EMSOUTEF=V27 = .809*F3 + .588 E27	.654
EMSDIST =V28 = .861*F3 + .508 E28	.742
EMSCAUSE=V29 = .716*F3 + .698 E29	.513
EMSACHV =V30 = .818*F3 + .576 E30	.669
EMSREASN=V31 = .685*F3 + .729 E31	.469
OPTSUB =V35 = .834*F4 + .551 E35	.696
OPTREDUC=V36 = .878*F4 + .479 E36	.770
OPTPROC =V37 = .824*F4 + .566 E37	.680
OPTPROD =V38 = .783*F4 + .622 E38	.613
OPTDIS =V39 = .751*F4 + .660 E39	.564
OPTRECYC=V40 = .713*F4 + .701 E40	.509
OPTSEG =V41 = .646*F5 + .763 E41	.418
OPTCREAT=V42 = .676*F5 + .737 E42	.457
OPTRELOC=V43 = .579*F5 + .815 E43	.336
OPTALL =V44 = .803*F5 + .595 E44	.645
OPTSPRED=V45 = .551*F5 + .835 E45	.303
OPTREPCK=V46 = .602*F5 + .798 E46	.363
OPTREMAN=V47 = .795*F6 + .606 E47	.632
OPTREBLD=V48 = .825*F6 + .565 E48	.681
OPTCONSM=V50 = .607*F6 + .795 E50	.369
ACTQUAL =V51 = .882*F7 + .471 E51	.778
ACTLT =V52 = .825*F7 + .566 E52	.680
ACTPOS =V53 = .861*F7 + .509 E53	.741
ACTPRODS=V54 = .834*F7 + .552 E54	.696
ACTCOST =V55 = .805*F7 + .594 E55	.647
ACTWEQIP=V56 = .801*F7 + .598 E56	.642
ACTINTER=V57 = .746*F7 + .666 E57	.557
ACTWPROD=V59 = .772*F7 + .636 E59	.595
ACTBENE =V60 = .747*F7 + .665 E60	.558
ACTIS =V61 = .664*F7 + .748 E61	.440

4.5 Cross Validation and Non-Response Bias

This section determines whether the factorial structures of the measurement model replicates across independent samples of the same population. Explicitly, this section addresses the issue of non-response bias, and cross validation. Here, the test involves whether the CFA model is equivalent across the first wave of responses and the second wave of respondses.

In testing multigroup analysis and the invariance across groups, sets of parameters are put to the test. A primary interest in multigroup analysis involves the constraints of the factor loading paths, and the factor covariances. When analyses focuses on multigroup comparisons with constraints between groups, it is essential that parameters for all groups be estimated simultaneously. When doing this, model specifications for each group must exist in the same file. This is accomplished by placing the input file for each group, one after the other. In this case, model specifications for the first wave of responses appeared first, followed by those for the second wave of responses.

When testing for invariance, only estimated parameters can have equality constraints. Therefore, testing was limited to the factor loadings and covariances. The results of the test for invariance are presented in Table 4.5. The results show the goodness of fit statistics for the entire model and the equality constraints between them. As indicated by a CFI of .82, the multigroup models represent a good, but not excellent fit to the data.

Table 4.5 Goodness-of-Fit Indices for the Multigroup Model.

CHI-SQUARE = 12226.075 BASED ON 2992 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001

BENTLER-BONETT NORMED FIT INDEX=	0.779
BENTLER-BONETT NONNORMED FIT INDEX=	0.818
COMPARATIVE FIT INDEX (CFI) =	0.824

ITERATIVE SUMMARY

ITERATION	PARAMETER ABS CHANGE	ALPHA	FUNCTION
1	3.216179	0.50000	20.48194
2	1.243865	1.00000	11.43102
3	0.058220	1.00000	11.29913
4	0.018777	1.00000	11.29057
5	0.007007	1.00000	11.28932
6	0.002495	1.00000	11.28912
7	0.001076	1.00000	11.28909
8	0.000394	1.00000	11.28908

The next table relates to the validity of the imposed equality constraints. The program reports the constraints specified and then presents results for both univariate and multivariate tests of hypotheses. Associated with each constraint is an LM χ^2 statistic. In EQS, a check on the related probability values determines if any of the tests are statistically significant. For the measurement model, all but four constraints resulted in probability values greater than 0.05, indicating that the hypothesized equality of the specified factor loadings and covariances held. Given the results, 93.9 % of the measures in the model are operating in the same way for both groups. Thus, it would be appropriate to combine these two samples for a test of the full structural equation model.

Table 4.6 Equality Constraints for the Multigroup Model

Using the Lagrange multiplier to test for releasing constraints of the multigroup model, all 66 paths in the model were constrained with the following univariate and multivariate results.

UNIVARIATE TEST STATISTICS:

CONSTRAINT			CHI-SQUARE	PROB
1	CONSTR:	1	0.247	0.619
2	CONSTR:	2	0.568	0.451
3	CONSTR:	3	0.918	0.338
4	CONSTR:	4	0.843	0.359
5	CONSTR:	5	0.405	0.525
6	CONSTR:	6	0.123	0.725
7	CONSTR:	7	0.005	0.946
8	CONSTR:	8	0.031	0.860
9	CONSTR:	9	0.159	0.690
10	CONSTR:	10	0.048	0.826
11	CONSTR:	11	1.373	0.241
12	CONSTR:	12	0.002	0.963
13	CONSTR:	13	0.716	0.398
14	CONSTR:	14	0.924	0.337
15	CONSTR:	15	0.004	0.950
16	CONSTR:	16	0.123	0.726
17	CONSTR:	17	0.173	0.678
18	CONSTR:	18	2.329	0.127
19	CONSTR:	19	0.562	0.453
20	CONSTR:	20	0.000	0.993

21	CONSTR: 21	0.182	0.670
22	CONSTR: 22	0.861	0.354
23	CONSTR: 23	0.000	0.997
24	CONSTR: 24	1.396	0.237
25	CONSTR: 25	0.656	0.418
26	CONSTR: 26	0.459	0.498
27	CONSTR: 27	0.006	0.940
28	CONSTR: 28	0.775	0.379
29	CONSTR: 29	0.132	0.717
30	CONSTR: 30	2.459	0.117
31	CONSTR: 31	1.114	0.291
32	CONSTR: 32	0.155	0.694
33	CONSTR: 33	0.566	0.452
34	CONSTR: 34	5.323	0.021
35	CONSTR: 35	0.351	0.553
36	CONSTR: 36	0.839	0.360
37	CONSTR: 37	0.440	0.507
38	CONSTR: 38	0.297	0.586
39	CONSTR: 39	0.085	0.771
40	CONSTR: 40	2.270	0.132
41	CONSTR: 41	6.263	0.012
42	CONSTR: 42	2.285	0.131
43	CONSTR: 43	1.619	0.203
44	CONSTR: 44	0.003	0.957
45	CONSTR: 45	0.014	0.907
46	CONSTR: 46	0.038	0.846
47	CONSTR: 47	0.069	0.793
48	CONSTR: 48	0.000	0.993
49	CONSTR: 49	0.366	0.545
50	CONSTR: 50	0.995	0.318
51	CONSTR: 51	1.576	0.209
52	CONSTR: 52	0.046	0.830
53	CONSTR: 53	0.604	0.437
54	CONSTR: 54	0.393	0.531
55	CONSTR: 55	0.300	0.584
56	CONSTR: 56	0.204	0.651
57	CONSTR: 57	4.556	0.033
58	CONSTR: 58	0.029	0.864
59	CONSTR: 59	0.814	0.367
60	CONSTR: 60	0.238	0.625
61	CONSTR: 61	3.864	0.049
62	CONSTR: 62	4.086	0.043
63	CONSTR: 63	1.684	0.194
64	CONSTR: 64	0.038	0.846
65	CONSTR: 65	0.807	0.369
66	CONSTR: 66	0.253	0.615

CUMULATIVE MULTIVARIATE STATISTICS: UNIVARIATE INCREMENT

STEP	PARAMETER	CHI-SQUARE	D.F.	PROBABILITY	CHI-SQUARE	PROBABILITY
1	CONSTR: 41	6.263	1	0.012	6.263	0.012
2	CONSTR: 34	11.901	2	0.003	5.638	0.018
3	CONSTR: 57	16.462	3	0.001	4.560	0.033
4	CONSTR: 61	20.240	4	0.000	3.779	0.052
5	CONSTR: 42	23.427	5	0.000	3.186	0.074
6	CONSTR: 63	26.019	6	0.000	2.592	0.107
7	CONSTR: 18	28.600	7	0.000	2.581	0.108
8	CONSTR: 30	30.605	8	0.000	2.005	0.157
9	CONSTR: 60	32.283	9	0.000	1.678	0.195
10	CONSTR: 51	33.675	10	0.000	1.392	0.238
11	CONSTR: 66	34.942	11	0.000	1.266	0.260
12	CONSTR: 62	37.050	12	0.000	2.109	0.146
13	CONSTR: 40	38.443	13	0.000	1.392	0.238
14	CONSTR: 24	39.601	14	0.000	1.158	0.282
15	CONSTR: 11	40.753	15	0.000	1.152	0.283
16	CONSTR: 50	41.900	16	0.000	1.147	0.284
17	CONSTR: 31	42.958	17	0.000	1.058	0.304
18	CONSTR: 3	44.015	18	0.001	1.058	0.304
19	CONSTR: 4	45.209	19	0.001	1.194	0.275
20	CONSTR: 43	46.223	20	0.001	1.014	0.314
21	CONSTR: 14	47.169	21	0.001	0.946	0.331
22	CONSTR: 53	48.044	22	0.001	0.875	0.350
23	CONSTR: 13	48.890	23	0.001	0.846	0.358
24	CONSTR: 5	49.719	24	0.002	0.829	0.363

25	CONSTR: 35	50.537	25	0.002	0.819	0.366
26	CONSTR: 32	51.443	26	0.002	0.905	0.341
27	CONSTR: 19	52.255	27	0.002	0.812	0.368
28	CONSTR: 38	52.958	28	0.003	0.703	0.402
29	CONSTR: 22	53.488	29	0.004	0.530	0.467
30	CONSTR: 28	54.021	30	0.005	0.533	0.465
31	CONSTR: 25	54.562	31	0.006	0.541	0.462
32	CONSTR: 26	55.016	32	0.007	0.454	0.501
33	CONSTR: 21	55.298	33	0.009	0.282	0.596
34	CONSTR: 16	55.540	34	0.011	0.243	0.622
35	CONSTR: 29	55.793	35	0.014	0.253	0.615
36	CONSTR: 65	55.998	36	0.018	0.205	0.651
37	CONSTR: 23	56.194	37	0.022	0.196	0.658
38	CONSTR: 20	56.371	38	0.028	0.176	0.675
39	CONSTR: 36	56.544	39	0.034	0.174	0.677
40	CONSTR: 27	56.706	40	0.042	0.162	0.687
41	CONSTR: 15	56.970	41	0.050	0.264	0.608
42	CONSTR: 9	57.124	42	0.060	0.154	0.694
43	CONSTR: 54	57.255	43	0.072	0.131	0.717
44	CONSTR: 7	57.382	44	0.085	0.127	0.722
45	CONSTR: 17	57.504	45	0.100	0.122	0.727
46	CONSTR: 64	57.638	46	0.117	0.134	0.714
47	CONSTR: 58	57.753	47	0.135	0.114	0.736
48	CONSTR: 59	57.974	48	0.153	0.221	0.638
49	CONSTR: 37	58.094	49	0.175	0.121	0.728
50	CONSTR: 48	58.211	50	0.199	0.117	0.732
51	CONSTR: 33	58.297	51	0.225	0.086	0.770
52	CONSTR: 47	58.384	52	0.252	0.087	0.768
53	CONSTR: 2	58.448	53	0.282	0.065	0.799
54	CONSTR: 52	58.505	54	0.314	0.057	0.812
55	CONSTR: 39	58.562	55	0.346	0.057	0.812
56	CONSTR: 45	58.600	56	0.380	0.038	0.846
57	CONSTR: 46	58.646	57	0.415	0.047	0.829
58	CONSTR: 44	58.688	58	0.450	0.041	0.839
59	CONSTR: 10	58.720	59	0.486	0.032	0.858
60	CONSTR: 55	58.746	60	0.522	0.026	0.871
61	CONSTR: 56	58.776	61	0.557	0.030	0.863
62	CONSTR: 8	58.800	62	0.592	0.025	0.876
63	CONSTR: 49	58.819	63	0.626	0.019	0.890
64	CONSTR: 6	58.829	64	0.659	0.009	0.923
65	CONSTR: 12	58.831	65	0.692	0.002	0.961
66	CONSTR: 1	58.833	66	0.722	0.002	0.969

Extrapolation methods of nonresponse bias are based on the assumption that subjects who respond less readily (i.e., in the second wave) are more like nonrespondendents. The most common type of extrapolation is carried over successive waves of a questionnaire. A wave refers to the response generated by a stimulus such as a reminder postcard (Armstrong and Overton 1977; Dillman 1978). Persons who responded in the second wave are assumed to have responded because of the stimulus and are expected to be similar to nonrespondents. With 93.9% of the paths in the model passing the multigroup comparison, the multigroup model analysis is evidence of a lack of nonresponse bias across the first and second wave of responses.

4.6 The Full Structural Equation Model

The full structural equation model in Figure 4.1 subsumes both the measurement model and the structural model. In the full SEM, latent variables are connected by one-way causal arrows, where the directionality reflects the propositions encompassing the causal structure of the model (as indicated by λ_1 and the β_1 in Figure 4.1).

The structural component of the model in Figure 4.1 represents the propositions that internal and external sources of uncertainty (F1 and F2 respectfully) are allowed to covary and will influence EMS development (F3). Additionally EMS development influences the different practices a firm may engage in, such as design, waste, and manufacturing practices (F4, F5, and F6). EMS development is also posited to directly influence operations performance (F7), and indirectly influence operations performance through the different practices of design, waste, and manufacturing. Next, analysis of the full model moves toward understanding identification and sample size.

4.6.1 Testing the Full Structural Equation Model

Section 4.6 discussed the analysis of nonresponse bias and results show good fit between the first and second waves of respondent. Thus, invariance is not an issue when attention turns to testing the full structural equation model. Consequently, group data can be pooled and the full model's analysis can be based on a single-group analysis (Joreskog

1971; Byrne 1994). As previously noted, a final sample size of 1331 was used for testing the full model. Table 4.7 contains the descriptive statistics of the data used for testing the full model.

Table 4.7 Pooled Data (full data set)

	N	Mean	Median	Std. Dev.
Respondent's Experience				
In current position (years)	1306	3-5yrs (3.26)	3.0	1.34
Public Ownership	623	.47	NA	.50
Foreign Ownership	235	.18	NA	.38
Private Ownership	535	.40	NA	.49
Joint Ownership	48	.0361	NA	.19
Annual Sales	1174	962,016	80,000	3,758,857

Using the phi matrix from the measurement model as input (see Table 4.8), the full SEM was estimated using both ML and ERLS. Estimation results for the full model are given using ML and ERLS (see table 4.9). ERLS estimation of the full model resulted in a $\chi^2_{(1331)}$ of 59.888 with a CFI value of 0.991. Based on the goodness-of-fit statistics there is a high degree of fit in the model. Additionally, the iterative summary only needed six for a convergent solution using ML and one for ERLS. The low number of iterations is also an indication of the specified model and the start values all being adequate.

Table 4.8 Phi Matrix Used for SEM

	F1	F2	F3	F4	F5	F6	F7
F1	1.00						
F2	.411	1.00					
F3	.198	.037	1.00				
F4	.235	.075	.707	1.00			
F5	.210	.033	.507	.738	1.00		
F6	.238	.077	.747	.831	.750	1.00	
F7	.217	.059	.679	.677	.562	.736	1.00

Table 4.9 Goodness-of-Fit Indices for the Full Structural Equations Model

MAXIMUM LIKELIHOOD SOLUTION
(NORMAL DISTRIBUTION THEORYGOODNESS OF FIT SUMMARY)

CHI-SQUARE = 35.951 BASED ON 8 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001

BENTLER-BONETT NORMED FIT INDEX=	0.992
BENTLER-BONETT NONNORMED FIT INDEX=	0.984
COMPARATIVE FIT INDEX (CFI) =	0.994
STANDARDIZED RMR =	0.039

ITERATIVE SUMMARY

ITERATION	PARAMETER ABS CHANGE	ALPHA	FUNCTION
1	0.749361	1.00000	3.39576
2	0.329272	1.00000	2.30894
3	0.224040	1.00000	1.32497
4	0.183857	1.00000	0.14306
5	0.017747	1.00000	0.03299
6	0.000088	1.00000	0.03298

ITERATIVELY REWEIGHTED GENERALIZED LEAST SQUARES SOLUTION (ELLIPTICAL DISTRIBUTION THEORY) LINEARIZED ESTIMATION)
GOODNESS OF FIT SUMMARY

CHI-SQUARE = 59.888 BASED ON 8 DEGREES OF FREEDOM PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS LESS THAN 0.001

BONETT NORMED FIT INDEX=	0.990
BENTLER-BONETT NONNORMED FIT INDEX=	0.976
COMPARATIVE FIT INDEX (CFI) =	0.991
STANDARDIZED RMR =	0.033

ITERATIVE SUMMARY

ITERATION	PARAMETER ABS CHANGE	ALPHA	FUNCTION
1	0.008738	1.00000	0.05494

The LM parameters identified by EQS as belonging in a model are based on statistical criteria. A more important way to evaluate the output is to look at the inclusion of the suspect path as substantially meaningful. Many of the parameters suggested in the output are not substantially meaningful and the model already has excellent fit. Thus, the parameters were ignored with respect to model respecification. Considering the fit, and the small magnitude of the LM χ^2 statistics, it can be argued that no additions to the model are required.

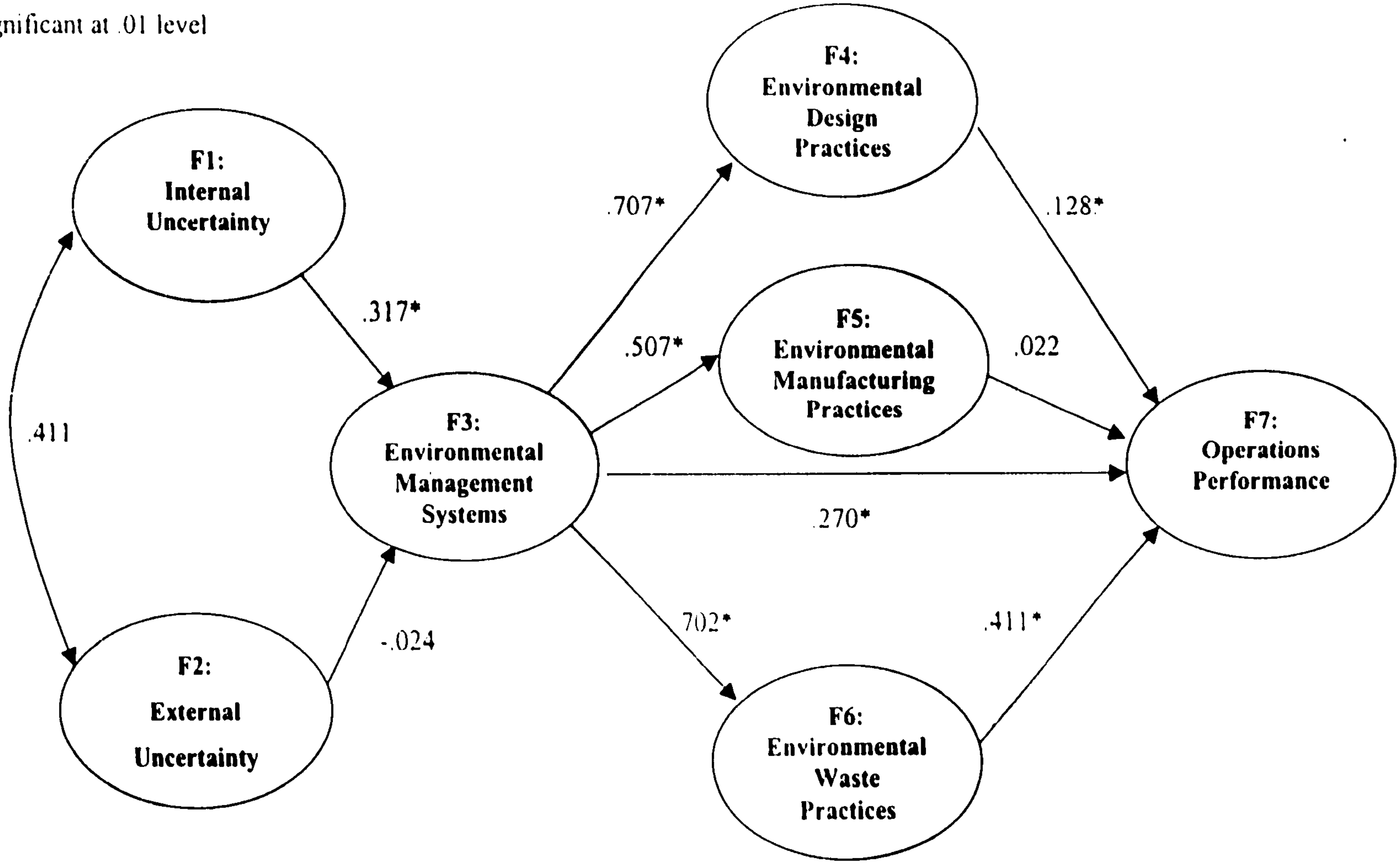
Table 4.10 Measurement Equations with Standardized Errors and Test Statistics

```
V3 =  .317*V1   - .024*V2   + 1.000 D3
       .032       .033
      9.751      -.741

V4 =  .707*V3   + 1.000 D4
       .021
     33.874

V5 =  .507*V3   + 1.000 D6
       .025
     19.931

V6 =  .702*V3   + 1.000 D5
       .020
     35.796

V7 =  .270*V3   + .128*V4   + .022*V5   + .411*V6   + 1.000 D7
       .030       .039        .032        .042
      9.079      3.316        .700       9.770
```

As discussed in the beginning of this chapter, the communication of hypotheses and results in the form of a structural equation model is both informative and parsimonious. The path diagram in Figure 4.3 represents the parameter estimates from the EQS analysis presented in Table 4.10.

FIGURE 4.3. FULL STRUCTURAL EQUATIONS MODEL USING ERLS ESTIMATION

* significant at .01 level



4.7 Testing The Firm Effect Variables

Based on the information presented in Chapters Two and Three, an additional aspect of this research looks at the effects of firm specific variables. These firm specific variables include: size of the firm using annual sales in quartiles, % sales to end customers, % sales to Europe, % sales exported, private ownership, foreign ownership, public ownership, joint ownership, and industry sector.

4.7.1 Testing of Firm Effect Variables

Assessment for firm effect analysis was performed using multiple regression. The seven variables posited as effecting the EMS construct in Chapter Two and Three were regressed on the item factor scores of the manifest variables for the EMS construct. Cohen and Cohen (1983) and Hair et. al. (1984) claim this approach is appropriate when testing dependence and the prediction of a metric dependent variable by other independent variables.

Initial analysis resulted in annual sales not significantly impacting EMS item factor scores. To reduce the variance in annual sales while still maintaining a linearized relationship to the dependent variable (Cohen and Cohen 1983), this variable was converted into the log of sales and found to then be significant in the regression procedure. One independent variable, public ownership was left out of the regression for comparison to the other ownership dummy variables. The results of the regression analysis show that size of the firm in log sales and private ownership are significant at the .01 level while joint ownership is significant at the .10 level. Those variables that did not have statistically significant results when regressed on the EMS constructs include: % of sales exported, % of sales to Europe, and the % of sales to the end customer, and foreign ownership. Finding no significant relationship between these variables and the EMS constuct helps to eliminate omitted variable bias from the structural equation model.

Table 4.11 Results of Regression Analysis

Model		Beta	Std. Error	Std. Coef. Beta	t	sig.
1[a]	(Constant)	-1.23	.216		-5.684	.000
	Logsales	.120	.018	.250	6.796	.000
	Export	-.0009	.002	-.020	-0.432	.667
	Euexport	-.0009	.004	-.013	-0.284	.776
	Endsales	-.0002	.001	-.007	-0.213	.831
	Foreign	.0573	.088	.023	0.653	.514
	Joint	.3320	.192	.058	1.728	.084
	Private	-.428	.072	-.211	-5.952	.000

Dependent Variable: Factor Scores for EMS construct with public ownership removed
[a]R Squared = .142 (Adjusted R Square = .134)

Industry sector was not tested in the initial regression analysis. Subsequent univariate analysis of variance with the item factor scores as the dependent variable, holding logsales constant, and the industry sector variable as the fixed independent variable was used to test differences in means and significance of beta weights of each industry sector on one omitted sector. *A priori*, it is hypothesized that the chemical industry would have greater incentive to develop an EMS due to stringent environmental regulations in place for that industry and public and governmental scrutiny of this industry since the early 1970s. When performing the univariate analysis of variance on the industry sectors, one dummy variable is removed from the group of dummy variables for comparison and operational purposes. The results of the univariate analysis of variance are presented in Table 4.12 And Table 4.13.

Table 4.12 Tests of Between Subjects Effects from Analysis of Variance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	182.372[a]	16	11.398	13.488	.000
Intercept	95.658	1	95.658	11.195	.000
Logsales	89.764	1	89.764	106.219	.000
Sector2	73.682	15	4.912	5.813	.000
Error	888.176	1051	.845		
Total	1071.123	1068			
Corrected Total	1070.548	1067			

[a]R Squared = .170 (Adjusted R Squared = .158)

Table 4.13 Parameter Estimates From Univariate Analysis of Variance

						95% Confidence Interval	
Parameter	N	B	Std. Error	t	Sig.	Lower	Upper
Intercept	NA	-1.173	.202	-5.802	.000	-1.570	-.77
Logsales	NA	.144	.014	10.306	.000	.117	.172
Automotive	183	-.355	.135	-2.638	.008	-.619	-.090
Agriculture	20	-.996	.245	-4.071	.000	-1.475	-.516
Computer	138	-.805	.140	-5.769	.000	-1.097	-.531
Fabricated Metal	160	-.595	.139	-4.296	.000	-.867	-.323
Food & Kindred	5	-1.346	.427	-3.156	.002	-2.183	-.509
Industry Machinery	113	-.663	.145	-4.566	.000	-.948	-.378
Laboratory/Medical	51	-.899	.172	-5.229	.000	-1.237	-.562
Other	150	-.361	.139	-2.595	.010	-.634	-.088
Office Systems	18	-.452	.263	-1.719	.086	-.968	.063
Other Manufacturing	194	-.331	.134	-2.468	.014	-.593	-.067
Pharmaceutical	41	-.280	.186	-1.505	.132	-.645	-.084
Printing	12	-.883	.300	-2.945	.003	-1.471	-.295
Transportation	21	-.856	.250	-3.423	.001	-1.346	-.365
Services	9	-1.338	.344	-3.888	.000	-2.014	-.663
Primary Metal	12	.127	.327	.389	.697	-.514	.768
Chemical	71	0[a]					

[a] This parameter is zero because it was removed from the model for comparison

Additional analysis included rerunning the measurement model with a new construct comprised of the firm effect variables. This construct reflects the extraneous firm effects. The results of the initial measurement model with the firm effect variables suggested elimination of all variables except sales and private ownership. Upon review of the modified SEM model with the firm effect construct, the multigroup approach was chosen instead of a two-staged approach to the inclusion of this new two-item construct, or two single item constructs in the model.

4.8 Summary of Data Analysis

This chapter tested the structural equation measurement model and full model proposed in chapter three. The measurement model estimation utilized both Maximum Likelihood and Elliptical Reweighted Least Squares due to multicolinearity. The measurement model has good fit with the data relative to the early stages of construct development in this field. The data also fit the full structural equation model very well with all fit indices over .90 and error term of .03. Next, the results of the propositions and hypotheses are individually summarized.

4.8.1 Summary of Propositions

Proposition 1: $\gamma_1 > 0$, $p < 0.05$ (Supported)
Internal uncertainty positively influences EMS development.

Proposition 2: $\gamma_2 > 0$, $p < 0.05$ (Not Supported)
External uncertainty negatively influences EMS development.

Proposition 3: $\gamma_3 > 0$, $p < 0.05$; $\gamma_4 > 0$, $p < 0.05$; $\gamma_6 > 0$, $p < 0.05$ (Supported)
EMS development is positively related with the environmental practices a firm participates in.

Proposition 4: $\gamma_7 > 0$, $p < 0.05$ (Supported)
Design practices are positively related to firm performance.

Proposition 5: $\gamma_8 > 0$, $p < 0.05$ (Not supported)
Manufacturing practices are positively related to firm performance.

Proposition 6: $\gamma_9 > 0$, $p < 0.05$ (Supported)
Waste practices are positively related to firm performance.

Proposition 7a: γ_3 & $\gamma_7 > 0$, $p < 0.05$; γ_4 & $\gamma_8 > 0$, $p < 0.05$; γ_6 & $\gamma_9 > 0$, $p < 0.05$ (Supported)
Operations performance is indirectly related to EMS through the environmental practices a firm is involved in.

Proposition 7b: $\gamma_5 > 0$, $p < 0.05$ (Supported)
Operations Performance is directly related to EMS.

4.8.2 Summary of Hypotheses Tested

Hypothesis 1: (Supported) There is a positive relationship between the size of firms and the status of the EMS.

Hypothesis 2: (Supported) Different industries will have different levels of EMS development.

Hypothesis 3: (Supported) Type of ownership will be related to the status of the EMS.

Hypothesis 4: (Not Supported) There is a positive relationship between the amount of European exporting and the status of the EMS.

Hypothesis 5: (Not Supported) There is a positive relationship between the amount of exporting and the status of the EMS.

Hypothesis 6: (Not Supported) The amount of sales to the end customer will have a positive relationship to the status of the EMS.

4. 9 Field Studies

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

Eight companies were selected representing different stages of the EMS certification process. Table 4.14 summarizes the status of the EMS development and the types of the firms visited.

Table 4.14 Categorization of Firms by EMS Certification Status

Status of EMS Development	Firms Visited
Not Being Considered	Firm A: Automotive Casting Facility Firm B: Metal Fastener Manufacturer
Assessing Suitability	Firm C: Office Furniture Manufacturer Firm D: Pharmaceutical Company
Planning to Implement	Firm E: Automotive Glass Assembly
Currently Implementing	Firm F: Break Systems Manufacturer Firm G: Automotive Glass
Successfully Implemented	Firm H: Engine Parts Manufacturer

In addition to representing different stages of EMS development, the selection of the firms was based on industrial affiliation (these firms represented a variety of industries; pharmaceutical, furniture, and automotive tier-one and tier-two suppliers), geographic proximity, level of contact and the firm's response to the large-scale survey.

For general information on the field research methodology and respondents see Chapter Three, Section 3.3. For a full discussion of the field research results, see (Melnyk, Calantone, Handfield, Tummala, Vastag, Hinds, Sroufe and Montabon 1999). The summarized results of the field studies can also be found in Appendix 3.

The purpose of the field visits was to identify the motivations for EMS adoption (as measured by EMS certification efforts) at different stages of implementation by a variety of firms. Additionally, the purpose of the research was to substantiate the findings from the large-scale survey. The subset of research questions used for this dissertation include:

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

4.10 Chapter Summary

To answer the primary and secondary research questions posited in this dissertation, Chapter Four reviewed the testing of propositions and hypotheses put forth in chapters two and three. Results indicate six of the eight propositions are supported by the results of the SEM data analysis. Additionally, half of the six hypotheses are supported by the regression and univariate analysis of variance data analysis.

This chapter has also briefly summarized the findings of eight field studies involving environmental management systems and firm environmental performance measures. The field research helps examine nonresponse bias, and enhance quantitative findings obtained from the large-scale survey through adding a description of systems and metrics behind the EMS development decision. Next, Chapter Five will discuss how these findings in Chapter Four relate to the existing body of research while presenting a new definition of an EMS, and then link this system to firm performance directly and indirectly. Chapter Five also assesses the contributions of the research for both practitioners and academic researchers. Finally, the next chapter explicates limitations of the research and future research directions.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Introduction

The purpose of this chapter is to interpret and discuss the data analysis from Chapter Four. Chapter Five builds on the results presented in Chapter Four and begins by discussing the propositions and hypotheses in greater detail. Section 5.3 develops a new definition of an Environmental Management System (EMS), while Section 5.4 examines the direct and indirect impacts of an EMS on operations performance. Section 5.5 assesses the contribution of the research from a managerial and research perspective. Section 5.6 discusses the limitations of the research. Finally, Section 5.7 explores future research directions, with concluding comments made in Section 5.8.

5.1.1 Research Questions

The goal of the dissertation is the investigation of the theoretical linkages between EMS and operations performance by answering primary and secondary questions. To better understand the linkages between EMS and operations performance, Chapters Two and Three discussed scale development, while Chapter Four tested several propositions and hypotheses. The primary and secondary research questions this dissertation answers are the driving force to both the managerial and academic contributions of the research. These primary and secondary research questions are reviewed here to set the stage for the rest of the chapter in discussing the theoretical linkages, propositions, hypotheses, and contributions to the field.

Primary Research Questions:

1. Is there an EMS construct? This will be demonstrated through construct validity and reliability results from Chapter 4.

2. What is the impact of EMS on operations performance? Through the demonstration of valid and reliable measures for seven constructs, Structural Equation Modeling (SEM) results from Chapter 4 reveal relationships between EMS and operations performance.

Secondary Research Questions:

3. What are the sources of uncertainty for the development of an integrated EMS?
4. What is the relationship between EMSs and the environmental practices a firm pursues? (For the context of this research, the environmental practices will be limited to design, manufacturing, and waste practices).
5. Is an EMS an example of resource productivity? (If the answer is yes, then it lends support to Porter and Van Der Linde's (1995a) arguments).
6. How do factors such as % of sales to end consumer, amount of export, European exports, ownership, and resources (size, sales, etc.) impact the "State of the EMS"?

As discussed in Chapter Three, EMS theory may be viewed as a system of constructs and variables in which the constructs are related to each other by propositions and the variables are related to each other by hypotheses (Bacharach 1989). A good EMS theory involves a clear explanation of how and why specific relationships lead to specific outcomes. Since EMS is new, most of the constructs are not well developed and a large number of manifest variables were used to capture the necessary validity and reliability underlying the proposed latent constructs (Hunt 1991). Next, the primary and secondary research questions are answered through discussing the propositions and hypotheses concerning the theoretical development of environmental management systems at the plant level, and their relationship with uncertainty, environmental practices and finally, operations performance.

5.2 Discussion of Propositions and Hypotheses

Proposition 1: (Supported) Internal uncertainty influences EMS development. $\gamma_1 = .317$, significant at the 0.01 level. Internal uncertainty is related to top management's decision-making policies, risk aversion, and the rate of change the firm is subject to. The results indicate that more aggressive management policies and environments where the internal rate of change and product development has increased will positively impact EMS development. Evidence from the field studies supports the results for proposition one with firms such as H, E, G, and D all having a proactive approach to environmental management. These same firms also had green corporate cultures, top management support, and better-developed EMSs than did other firms without green corporate cultures.

The overall results support the idea that risk averse managers are hesitant to pursue environmental initiatives such as an EMS. This may be due to not being sure of the cost/benefit trade-off (Mroz, 1997). Additional support for this relationship is found in Sroufe, Curkovic, Montabon, and Melnyk (1999) where multiple field studies show managers wait until others have undergone green projects, or until customers demand it.

Proposition 2: (Not Supported) External uncertainty negatively influences EMS development. $\gamma_2 = -.024$, not significant at the .05 level. The results are counterintuitive. Given the general principles of the industrial organization model (Bain 1956; Scherer 1970), the structure of the external environment should have an impact on conduct of the firm. This portion of the model generally borrows from the paradigm of industrial organization, and specifically from the Structure - Conduct - Performance (SCP) literature (Porter 1979, 1981, 1991a; Miller 1987; Rumelt 1991) that all claim the external environment will impact the conduct of the firm. While SCP posits that industry structure will dictate the actions necessary for firms within an industry and this will in turn affect the performance of the firm, the results indicate the lack of a relationship.

External uncertainty consists of the concern over the rate of new product introduction in the industry, the rate of change in technology and the ability of the firm to accurately predict changing consumer needs for products. While this relationship is not significant, the results may reflect what was happening with EMS certification and the external pressures for EMS development at the time of data collection. Firms A and B from the field studies claim they will not develop an EMS unless this is mandated from the firm's customers. At the time of the field studies and the survey, external pressures had not mandated suppliers to develop and certify EMSs.

Of additional interest when discussing propositions 1 and 2, is the covariance of internal and external uncertainty. In the full SEM, these two exogenous constructs were allowed to covary. With a correlation of .411, these two constructs are highly correlated, yet only one has a significant relationship with the EMS construct. The multicolinearity of the data discussed in Chapter Four may be a contributing factor to the high correlation between constructs, and affect the relationship between external uncertainty and EMS in the presence of the internal uncertainty construct.

Alternative explanations for the results of proposition 2 include firm perceptions of the external environment not influencing internal decisions. Additionally, these internal decisions involve levels of perception that impact tactical decisions, while the decision to implement an EMS may be strategic. While discriminant validity was established in Chapter Four, future research and analysis will examine the uncertainty constructs in a competing models approach to structural equation modeling.

Proposition 3: (Supported) EMS development is positively related with the environmental practices a plant participates in. The results show γ_3 equal to .707, p-value

< 0.05 for the relationship to design; $\gamma_4 = .507$, p-value < 0.05 for the relationship to manufacturing practices; and $\gamma_6 = .702$, p-value < 0.05 for the relationship to waste practices. Thus, EMS does positively impact the environmental practices present in the hypothesized model. The EMS construct involved variables such as the extent of a firm's formal EMS, top management support for the system, the documentation, tracking and reporting of environmental information, use of performance goals, training, internal and external perceptions of the system. The EMS construct has strong relationships to environmental design, manufacturing and waste practices posited. The resource-based view discusses capabilities creating a competitive advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). It is here we can see the formal EMS, documentation, goals, and training providing information at the plant level which allows for the use of the different environmental practices.

The first primary research question asks, "what is an EMS?" Based on the literature review, and testing of the measurement model in Chapter Four, an EMS can be defined and described from the nineteen manifest variables that comprise the summated scale for the EMS construct. The assumption is that this construct is complete based on a literature review that included access to over 12,000 Environmentally Responsible Manufacturing citations, and the omission of over 20 additional EMS instrument items that were available for use in this research. With more measures of the EMS construct available than needed, the results of the measurement model demonstrate a consistent and comprehensive EMS construct.

The results of the measurement model and summated scale demonstrate construct validity and reliability, while the full SEM links this new construct to environmental practices and operations performance. After testing the measurement model, a framework can be developed that better defines an EMS and details to what extent a plant is involved in each of the nineteen variables that comprise this latent EMS construct. This framework helps bring about a greater awareness of EMS practices. This definition and framework are discussed in greater detail in Section 5.3.

Information from the field studies shows that many of the firms involved in the certification of an EMS i.e., firms E, F, G, and H, had linked these systems to design and waste metrics. Therefore, direct relationships between the EMS and environmental design and waste practices are measured, tracked and managed in these types of firms. Additional information from the field studies supports the literature suggesting plants having key executives that aggressively pursue environmental growth opportunities will be more inclined to invest in an EMS.

If the EMS is looked upon as an investment in environmental initiatives, then the assumption can be made that the plant's environmental performance will be enhanced. Proposition three supports the general theory that environmental initiatives such as an EMS will affect environmental practices in terms of environmental design, manufacturing, and waste practices.

The second primary research question calls for an investigation of the relationship between EMSs and operations performance. To better understand the impact of an EMS on operations performance attention next turns to the mediated relationships (through environmental design, manufacturing, and waste practices) between EMSs and operations performance. Propositions 4 through 6 discuss the mediated relationships.

Proposition 4: (Supported) Design practices are positively related to firm performance. $\gamma_7 = .128$, p-value < 0.05. This relationship is relatively small, but significant. Design practices include the use of substitution, reduction of materials contributing to environmental problems, the use of product and process redesign to eliminate potential environmental problems, redesigning to aid in disassembly, and the increased use of recycled components.

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

Fullerton 1992; Allenby 1993; Sroufe, Curkovic, Montabon, and Melnyk 2000). An additional opportunity for waste minimization can be found in the manufacturing practices. Next, proposition 5 discusses the relationship of the manufacturing practices construct to operations performance.

Proposition 5: (Not supported) Manufacturing practices are positively related to operations performance. $\gamma_8 = .022$, p-value > 0.05. This relationship, defined very narrowly to include only remanufacturing, rebuilding and the consumption of waste internally, is not as posited. Manufacturing practices, as operationalized, include remanufacturing, where none of the parts are reduced to raw materials, and rebuilding where some of the parts or components are recovered while others are replaced, and the consumption of materials internally i.e., the consumption of waste materials to generate electricity.

Based on the results of this dissertation, there is a need for further examination of the relationships posited and demonstrated in this dissertation. Environmental manufacturing practices may be overlooked by certain industries, and firms are finding performance improvements from investments in manufacturing technology (Klassen 2000), and now design, and waste practices. Since manufacturing practices are strongly cross-functional, product design activities will impact multiple stakeholder (Polonsky and Ottman 1998; McDaniel and Rylander 1993), but are not typically focused on to the point that manufacturing is then overlooked.

In the dynamic environment captured by the SEM, environmental manufacturing practices, while correlated with operations performance, may be overlooked in the presence of design and waste practices. The results uncover a relationship in which the impact of these manufacturing practices is dependent upon the type of user within the plant, or the type of industry. At the manufacturing level, users may not see what is happening at the strategic level of the firm. The results support the idea that these narrowly defined environmental manufacturing practices do not impact the strategic dimensions of the plant and their impact may only be tactical when assessed across all industries in the sample. Further examination is still warranted.

The SEM results are also echoed by the field studies. The case studies show that for all of the firms involved in EMS development, or certification, i.e., E, F, G, H, and firm D, these firms focused on some design, very little manufacturing, and primarily waste, or output practices and performance measures. Given this, these firms were not measuring, monitoring, or managing environmental manufacturing practices with as much attention as design and waste practices. With regulations and special interest groups turning attention to waste reduction, firms may only focus on output wastes from a corporate social performance perspective (Wood 1991; Pava and Krausz 1996). Testing proposition 6 demonstrates this is not necessarily true and waste reduction practices impact more than social performance, and actually impact operations performance as well (Klassen and Whybark 2000a, 2000b).

Proposition 6: (Supported) Waste practices are positively related to firm performance. $\gamma_9 = .411$, p-value < 0.05. There is a relatively strong relationship between waste practices and operations performance. Thus, EMS impacts waste management practices directly and operations performance indirectly. Waste practices include: use of waste segregation; selling waste as an input to another product; the use of relocating a process or plant to take advantage of more favorable environmental regulations; the use of alliances with suppliers or customers to address environmental problems; an increased shifting of responsibilities to third parties better able to deal with the issues; and an increased use of returnable packaging to reduce solid waste. Much the same as the results from proposition 5 and the field studies, there seems to be ample evidence of firms using environmental waste practices and these waste practices do impact operations performance.

The results support the idea that initiatives such as segregation, selling of waste and alliances are better than those of traditional, inefficient ways of dealing with environmental issues in a reactive, ad-hoc, end-of-pipe manner (Global Environmental Management Initiative 1996). 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. These practices lend themselves well to an extension of Just-In-Time (JIT) practices and may also be examples of Porter and Van der Linde's (1995a) philosophy of resource productivity.

Secondary research questions call for the examination of the environmental practices a plant pursues, and the presence of practices resembling resource productivity (Porter and Van der Linde 1995a). The design, manufacturing, and waste related practices described in propositions 3 through 6 expose relationships that to date have not been tested in the literature. Additionally, the testing of propositions 3 through 6 provide evidence of better resource utilization and resource productivity as defined by Porter and Van der Linde (1995a). One interesting result is the presence of a manufacturing paradox. This paradox is the result of the operationalized environmental practices not impacting operations performance. Next, propositions 7 a and b, discuss the indirect and direct relationship between EMS and operation performance.

Proposition 7a: (Supported) Operations performance is indirectly related to EMS through the environmental practices a firm is involved in. As evident from the SEM results and propositions 4 and 6, the only non-significant path is between manufacturing practices and operations performance. As discussed in proposition 5, the relationship between manufacturing practices and operations performance is not as posited, but the correlation between constructs is relatively strong. Thus, proposition 7 "a" is supported with the caveat that the narrowly define construct of environmental manufacturing practices does not facilitate an indirect relationship to operations performance. Tibor and Feldman (1996) support the overall results for proposition 7a by claiming that environmental management will lead indirectly to better environmental performance. The premise is that improved systems associated with EMSs, such as those used in design, manufacturing, and waste practices of plants, will make achievement of performance goals more likely (Tibor and Feldman 1996).

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

Finally, as discussed in propositions 3 through 6, the field studies support the overall findings that EMSs are indirectly related to enhanced operations performance. Interviews at firms F, and D show that plants are realizing there are many hidden environmental costs and that these costs can now be tracked, and managed to reduce costs while also giving more leverage to the environmental function. In summary, indirect relationships between EMSs and firm performance are present in the hypothesized model.

Proposition 7b: (Supported) Operations Performance is directly related to EMSs. $\gamma_5 = .270$, p-value < 0.05. This is a relatively small relationship that is positive. Based on the results of the data analysis, there is a direct relations between the extent of a plants EMS, top management support for the system, documentation, tracking and reporting of environmental information, use of performance goals, training, internal and external perceptions of the system … and operations performance. This relationship demonstrates that a well-developed EMS will positively impact quality, decrease costs and lead times, improve the firm's position in the marketplace, bring about better products, help equipment selection decisions, reduces waste in production, improves chances of selling products in international markets, and has benefits that outweigh the costs.

If the competitive position of a company is strongly impacted by its response to environmental issues as (Bavaria 1996) suggests, than properly implementing an EMS, can ensure that they effectively manage environmental risks while identifying and exploiting the opportunities environmentally responsible manufacturing can bring (Global Environmental Management Initiative 1996). Results of the research indicates an EMS is related to more than just environmental performance in that these types of systems also impact improved products and plant image, reduced lead times and costs, and much the same as investments in technology and findings of Klassen (2000), also improve quality. The field studies show that firm F was able to prove the environmental function within the plant is a "benefit and not a cost" to the organization. Additionally, the information from the respondents in the field studies at firms C, D, F and H all suggest that the benefits of an EMS outweigh the costs.

Thus far, the development of EMS theory has been discussed as a web of constructs related to each other by propositions. To further support the examination of the secondary research questions, the variables involved in firm effects are related to each other by hypotheses and discussed in greater detail.

Summary of Hypotheses Tested

Hypothesis 1: (Supported) There is a positive relationship between the size of firms and the status of the EMS. Based on the results of the regression analysis, and follow-up analysis of variance with industry sectors, sales in its log form has a $\beta = .120$, p-value of .000 when regressed on the EMS factor scores, while holding several types of exporting, endsales, and types of ownership constant. Additionally, the univariate analysis of variance results show a beta of .144, with a significance level of .000. The convergence of the results indicates a significant and positive impact of firm size and the status of an EMS.

Some of the factors impacting the development and implementation of an EMS include the size of the plant, and resource availability. Given the scarcity of resources in a small plant environment, money and human capital may not be sufficient to support the development of a formal EMS. Therefore, the real test of EMS acceptance may be found in the number of small firms that adopt and implement these systems. Those firms with a formal system, documentation, tracking and reporting of results, training and the dissemination of environmental information to internal an external stakeholders are more likely larger firms in mature industries that have been dealing with environmental issues for some time. This type of industrial setting will have a relatively small number of large firms.

Information from the field studies show that smaller firms such A and B, lack formal EMSs. These smaller firms involved in the field studies did not want to invest in this technology unless it was mandated and did not require high costs. Conversely, the larger firms in the field studies, i.e., C, D, and H all have well established formal EMSs and have proactively invested in these types of systems. The relationship between the size of the firm and the EMS has been established. Attention next turns to an additional variable impacting EMS development. This variable is the industry in which the firm competes.

Hypothesis 2: (Supported) Different industries will have different levels of EMS development, and the chemical industry should have the most developed EMS. Results of the univariate analysis of variance show different industries Beta weights are less than those of the chemical industry and all beta weights are statistically significant at the .05 level with the exception of office systems, pharmaceutical, and primary metal industry sectors. The chemical industry tends to have a more developed EMSs as posited. Additionally, the primary metals industry is known for strict environmental regulations. The focus on environmental compliance by this industry and the development of EMSs to support environmental health and safety and operations helps attribute to the lack of difference from EMSs in the chemical industry. Much the same as the results from hypothesis one, industries with a relatively small number of large firms such as the chemical and pharmaceutical industries will have better developed EMSs. Using the beta weights from the univariate analysis of variance the following industries have EMSs ranked from most developed (relative to the chemical industry) to least developed.

Table 5.1 ANOVA Results

Parameter	B	Sig.
Intercept	-1.173	.000
Primary Metal	.127	.697
Pharmaceutical	-.280	.132
Automotive	-.355	.008
Office Systems	-.452	.086
Fabricated Metal	-.595	.000
Industry Machinery	-.663	.000
Computer	-.805	.000
Transportation	-.856	.001
Printing	-.883	.003
Laboratory/Medical	-.899	.000
Agriculture	-.996	.000
Services	-1.338	.000
Food & Kindred	-1.346	.002

Arora and Cason (1995) reveal companies emitting the largest amounts of toxic releases are the most likely to take part in a voluntary environmental program. This appears to also be true of EMS development. Since companies emitting the largest amount of toxic releases are typically concentrated in certain industries, such as the chemical and pharmaceutical industries. Examining the industry effect is of importance to research in this field to help focus research attention. Arora and Cason's results reveal that voluntary programs may achieve substantial reductions because they target those forms with the greatest reduction potential. This may also be true of EMSs.

Interestingly enough, both pharmaceutical and primary metal industries are not significantly different from the chemical industry. This should not be much of a surprise given the high level of environmental regulations imposed on both of these industries. From the field studies, the one pharmaceutical company interviewed had a well developed, formal EMS that was to be put in place globally to help with the handling of hazardous materials and pollution prevention. The chemical and pharmaceutical industries tend to have a high degree of involvement with hazardous materials, historical pollution problems, and environmental regulations to comply with. To a lesser degree manufacturers involved in printing, laboratory equipment, agricultural products, services, and the food and kindred products have potentially less hazardous materials, and fewer environmental regulations to comply with. Additionally, these industries are not typically associates with pollution problems to the extent the other industries are. Therefore, the results are as posited. Firms with more external and internal environmental pressures have developed integrated EMSs, where firms in industries without these pressures have not developed EMSs to the same extent, or are still waiting to develop such systems.

Hypothesis 3: (Supported) Type of ownership will be related to the status of the EMS. The regression results indicate that of the four types of ownership studied, i.e., private, public, foreign, and joint, private ownership is related to the EMS construct having a $\beta = -.428$, p-value of .000 when regressed on the EMS factor scores and holding size of the firm in annual logsales, exporting, and sales to the end customer constant. The regression analysis using dummy variables for types of ownership, with public ownership absent from the model, shows a difference in means between private and public ownership.

Joint ownership is significantly different than public ownership at with a $\beta = .332$, p-value =.084. The results indicate private ownership is negatively related to the development of an EMS relative to public ownership.

Converging the results with those of hypothesis 1, privately owned small firms may be some of the last firms to adopt an EMS. An example of this is found in the field study of firms A and B. These firms are privately owned and do not have a formal EMS. These firms view the development of an EMS as something they will do only if customers mandate it.

. The results are also interesting given discussions with firms such as F and G whose foreign ownership and management has influenced the decision of the firm to pursue EMS development and certification. There may be some conflict between what firms say they are doing and what they are actually doing. These results may also be present do to a lack of customers mandating certification of an EMS at the time of the study.

Next, the relationships of EMS and exporting, the amount of exporting to Europe and the amount of sales to the end customer are examined in hypotheses 4 through 6.

Hypothesis 4: (Not Supported) There is a positive relationship between the amount of European exporting and the status of the EMS. Based on the regression results, this relationship is not present in the data. Considered by some as being more environmentally conscious, European countries have developed environmental legislation and standards to promote environmental business practices (Klassen and Angell 1998). Given the environmentally conscious cultures of European countries, firms may choose to develop an EMS to demonstrate alignment with these cultures, and environmental standards. The results are counterintuitive given the literature claiming that European markets may demand EMS certification, and the amount of environmental standards in Europe (Tibor and Feldman 1996). Klassen and Angell (1998) note that German managers reported significantly higher levels of environmental ambitions than American counterparts. It appears this ambition has not fully transcended to those firms exporting to Europe, or to customer relations with those suppliers to European firms. With none of the firms interviewed in the field studies exporting more than a 2% of annual sales to Europe, the field studies lack additional insight as to why there is no relationship between exporting to Europe and EMS development.

Hypothesis 5: (Not Supported) There is a positive relationship between the amount of exporting and the status of the EMS. Based on the regression results, this relationship is not present within the data. The basic assumption is that the more the firm exports, (especially to Europe in hypotheses 4), the greater the incentive to have a well developed EMS in place to help with international regulations and environmental supplier audits. Much the same as hypothesis 4, a statistically significant relationship between exporting and EMS development is lacking. Also resembling hypothesis 4, none of the firm interviewed in the field notes are heavily dependent on exporting a large part of their annual sales, and additional insights are not gained from the field studies.

Hypothesis 6: (Not Supported) The amount of sales to the end customer will have a positive relationship. Based on the regression analysis, this relationship is not present within the data. Testing this relationship can also be viewed as a proxy for consumer spending.

It is posited that the amount of sales to the end customer will impact the development of an EMS. Based on the sample, this is not the case. Potential reasons for the results include internal issues of the plant and the possibility that the end customer does not matter. This would apply mostly to lower-tier suppliers. The results may also be an indication of North American impacts and a subsequent reflection of the marketplace where end customers may say yes to greener product, but make the final decision based solely on costs. Additional insights may come from firms that downplay the consumer and focus on supply chain issues (Fine 1998).

Those firms farther down the supply chain may not have the same requirements or incentives imposed on them as do the tier one suppliers of an Original Equipment Manufacturer. If the end customer requires environmental audits, or there is a possibility that certified EMS will be required for the supply chain (Bergstrom 1996; Daniels 2000), than it will be to the firms advantage to have an EMS to aid in this process. The lack of these requirements is changing. This shift in requirements for suppliers is due to the mandate of the automotive industry to have ISO 14000 certification for supply chain members (Daniels 2000). If the amount of sales to the end customer is to impact the development of an EMS, then customers are going to have to start demanding the presence of such systems in their suppliers. Longitudinal analysis may reveal the presence of this relationship.

5.3 Defining an EMS

As discussed in Chapter Two, one of the only definitions of an EMS is: "the organizational structure, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental management" (ISO 14001 1996). The purpose of a new definition of an EMS is to operationalize and empirically tests this new construct. With definitional ambiguity leaving practitioners with few frameworks and insights, researchers need to understand how to measure and operationalize the EMS construct. Very little good research exists as to what the defining attributes of an EMS really are, or how EMSs impact firms. A new definition of an EMS can go a long way toward a better understanding of what does and does not constitute an EMS and what activities plants should be engaged in. A better definition of an EMS will help explain and predict what activities should be engaged in and where scarce resources should be allocated.

EMS construct development is based on the literature review, experiences of the researcher, propositions, hypotheses and subsequent results of the data analysis. The results of the measurement model, much the same as a confirmatory factor analysis indicate construct validity and reliability for the nineteen manifest variables comprising the latent EMS construct. Additional analysis using the standardized coefficient alpha for the EMS construct results in a .9777 for this summated scale. Therefore, using the manifest variables from the EMS construct and the information from field visits, a more detailed definition of this type of system can be developed.

> 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.

Implementation an EMS requires a range of activities. First, training helps to ensure that workers operate equipment and production processes correctly and are proactive with respect to addressing environmental risks. Second, product design and development practices (e.g., Design for Environment) help reduce the use of raw materials and the generation of hazardous waste. Third, environmental risk assessment is performed throughout the product life cycle by summarizing and reporting of environmental information. Fourth, monitoring to ensure that manufacturing operations are in compliance with pollutant emission standards, regulatory requirements, or internal performance goals. Finally, communicating accomplishments efficiently, clearly, and credibly to all interested stakeholders is very important (Feldman, Soyka, and Ameer. 1997). EMS facilitates environmental information dissemination and is able to provide specialized information used for decision support, reporting to top management, and reporting to the external stakeholders of the firm. Next, the importance of the relationship of an EMS to operations performance is discussed.

5.4 The Link to Firm Performance

This link has been established both indirectly and directly through the results in Chapter Four and propositions 7a and 7b. Melnyk and Handfield (1995) define Environmentally Responsible Manufacturing (ERM) as a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing its effect on the environment while also trying to maximize resource efficiency. Additionally, Klassen and Whybark (2000b) 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 support EMSs being linked both directly and indirectly to ERM, the environmental technology portfolio, and operations performance. While the link to better environmental performance is not surprising, the link to improved operations performance is both interesting and arcane. Expected benefits of ERM include safer and cleaner facilities, lower future costs for disposal and worker protection, reduced environmental and health risks, and improved product quality at lower cost and higher productivity (Sarkis and Rasheed 1995). EMS appears to be one means of meeting the environmental challenge posed to firms contemplating ERM practices. Companies have come to recognize that reduced environmental impacts and the institutionalization of ERM can lead to improved operations and profitability (Epstein 1996). The link between ERM systems and TQM systems is one that has already been established (Curkovic 1998). Based on the results of the data analysis, EMSs now appears to be a system that impacts quality and operations performance while also extending TQM to Total Quality Environmental Management (TQEM).

Porter (1991a) reveals several "win-win" environmental situations, while Walley and Whitehead (1994) discuss the idea that win-win situations are rare and overshadowed by a firm's total cost of environmental programs. EMSs appear to be an example of resource productivity and examples of win-win situations for firms seeking better environmental and operational performance.

If firms choose to use existing EMS frameworks, i.e., ISO 14000, or BS 7750, then system development and the link to firm performance will be much the same as systems developed for TQM and ISO 9000. The field studies suggest firms already involved in ISO 9000 have used this standard as a platform for EMS development. The EMS standards have the same set of basic elements. These elements are much the same as the Deming cycle and include: (1) creating an environmental policy; (2) setting objectives and targets; (3) implementing a program to achieve those objectives; (4) monitoring and measuring its effectiveness; (5) correcting problems; and, (6) reviewing the system to improve it and its overall environmental performance. The results and field studies support the claim that firms making investments in environmental health and safety initiatives that are not required by international laws, social standards, or in the interest of maximizing short-term profits, find the investments do pay off in the long-term (Rondinelli and Vastag 1997). Using Florida's (1996) findings that firms are leveraging their industrial modernization strategies toward environmental ends, EMSs should be one element of a modernization strategy.

The resource-based view of the firm posits a competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by a firm's competitor (Rumelt 1984). Using the results of hypotheses 1 through 6, it appears that EMSs are not prevalent in all types of firms or industries. This may be due to a lack of human and capital resources. Much like Barney's (1991) resource-based view of the firm, EMS resources can be valuable, rare, and in fact raise barriers to imitation, and entry. If competitive advantage is rooted inside a firm's resources and assets as Itami (1987); Wernerfeldt (1984); and Peteraf (1993) suggest, then the potential of being the first to adopt an EMS as a unique resource should provide many benefits to the firm. The benefits can be in the form of valuable information (e.g., costs of wastes, training, goals, and documentation for auditing and public environmental information) both internally and externally to the firm. This plant specific, unique information may be inimitable to other firms within the industry, or inimitable to firms contemplating entry. An EMS provides information that can be used to aid decision making, enhance firm image, or if part of a certified standard, can facilitate entry into markets having legal restriction on entry to only those firms with a certified EMS (Daniels 2000). Borrowing from Melnyk and Denzler (1994) and the resource based view of the firm, a unique resource such as an EMS can provide specialized information that can enhance the benefits and value equation (e.g., quality, speed, flexibility, and costs) or a firm.

Additional benefits include using an EMS as a means for companies with typically bad environmental practices to demonstrate a change in ways (Litskas 1999), or improved corporate social performance (Waddock and Graves 1997). The field studies also support the use of EMSs as a means of improving public image and corporate soial performance. This improved social responsibility can be seen as a product the firm has to offer to the key publics of the firm (Murry and Montanari 1996). Society is demanding social responsiveness at a minimum, and the call for social responsibility seems to be getting louder and clearer (Pizzolatto and Zeringue, 1993). EMSs are one way firms can improve social responsibility through the tracking, monitoring, and reporting environmental performance, training, and providing information to external stakeholders of the firm.

5.5 Assessing the Contributions of the Research

5.5.1 Managerial Contributions

The results are of interest to managers faced with decisions regarding EMSs and environmental practices. While some view environmental projects as a "cost of doing business," results of the research provide evidence of benefits such as cost reduction and quality improvement. The results of this research also help practitioners understand what defines a well-developed EMS and what firms are actually doing with EMSs. The research is a step in the direction toward resolution of the conflict between competing paradigms that drive environmental manufacturing practices. While the competing paradigms either argue for resource productivity (Porter and Van der Linde 1995a), or costs that exceed benefits (Walley and Whitehead 1994), the results of this research indicate that EMSs can positively impact operations performance and have benefits that exceed the costs.

The results of the structural equation model demonstrate the link of environmental practices to more than just environmental performance. The research also shows a compelling reason for the link to critical operations performance measures such as cost, quality, lead-time, and reputation in the marketplace. Additionally, there is evidence to support the claim that plant reputation, and a better position in the marketplace, can result from EMS development and the environmental practices a plant pursues. Interestingly, environmental manufacturing practices such as remanufacturing and rebuilding are not impacting improved operations performance while in the presence of the other practices such as design and waste. This may be due to a very dynamic environment and an overpowering mediating relationships between EMS and operations performance. This creates an opportunity for manufacturing personnel to make sure they are involved in both design and waste management practices.

Finally, the EMS construct is now better defined, and based on current practices of manufacturing firms in North America. This research gives structure to the EMS construct, with a resulting definition and framework established. Practitioners can view the results of this research as an explanation of the dynamic relationships that surround EMSs, and as a guide to opportunities for both environmental and operations improvement.

5.5.2 Research Contributions

From a research perspective, the goal is to develop and assess a rationally consistent theory of EMSs. Operationalizing the EMS construct has bridged gaps in the operations management literature while simultaneously building theory. The multimethod approach of qualitative and quantitative data collection and analysis lends itself well to the development of valid and reliable scales (Cresewell 1994) for the EMS construct. Theory building is supported through the explanatory and predictive powers of the model and results. The total effects of the model demonstrate many posited relationships across multiple industries and several levels of management. Future research will explore single industries, and relationships among single management levels

The structure of EMSs is more clear and sound. Construct validity, reliability as demonstrated in the measurement model, and the information from the field studies come together to better define current EMS practices and relationships. While environmental practices have been thought to impact only environmental performance, the results of the research how show theoretical and causal linkages of EMSs to more than environmental practices. These relationships support a consistent theory of EMSs.

The relationships tested in this research are dynamic and not straightforward. Causal linkages between EMSs and operations performance are theoretically complex, and both indirect and direct. The complexity of testing these relationships dealt not only with the accumulation of data and theory to build and test a model, but also with issues of non-normality and theory development. The complex relationships uncovered by this research demonstrate what constructs and relationships are important, while also bringing about multiple unresolved issues surrounding those relationships that are not significant in the hypothesized model.

5.6 Limitations of the Research

The limitations of this research include the use of a survey, social bias toward environmental issues, self-reporting bias, the method of analysis used, and the embryonic state of empirical research in this field. The first limitation to this research involves survey-based research being criticized for decreasing response rates. This research reflects the degree of difficulty involved in getting a high response rate for a 16 page, 235 item survey instrument. While the survey or the field studies alone have some weaknesses, the combination of the two overcomes these weaknesses and focuses on the strengths of each. Self-reporting bias is also part of any survey requiring perceptive measures of items. While survey development strived to reduce the self-reporting indulgences, there is always the potential for this type of bias.

Additionally, the survey is a snapshot in time, 1997. Longitudinal information would better establish the model, constructs, and the manufacturing plant environment if tested over time. Additionally, the timing of the survey (one year after the release of ISO 14000) means that many firms were in the early stages of EMS certification, awareness, or development. More recent events such as the auto industry requiring EMS certification will bring about a greater development of EMSs.

The next limitation involves the use of multivariate analysis. SEM techniques allow correlation between variables to be controlled for, and allow for measurement error (Bollen 1989). The limitation of this methodology is that it can only serve to disconfirm a model, not prove it (Handfield and Ghosh 1997). Basically, the conceptual model in figure 1.1 is designed to only test whether the theoretical model can be rejected. The model does not establish causality.

Finally, an obstacle to this research includes the topic of environmental management systems and environmental business practices being in the early stages of development. With many normative, but few good empirical articles to draw from, the dearth of research calls for both qualitative and quantitative research. Thus, the approach of this dissertation is that of drawing from several disciplines such as operations management, strategy, marketing, and new product design while using both qualitative and quantitative methods. This approach is both time and resource intensive.

5.7 Future Research

Future research endeavors include: (1) the development of frameworks to help firms understand EMS development and cross-functional integration; (2) exploring unresolved issues and testing competing explanations; (3) testing whether or not EMSs are strategic, tactical, or operational resources; (4) testing the extent to which EMSs are customer driven or compliance driven; (5) finding omitted variables; (6) environmental metrics; (7) longitudinal examination of the results; and finally, (8) extensions of the research to other fields.

Future research opportunities include using a dual approach to qualitative and quantitative data collection, case studies and empirical analysis. This approach lends itself well to the development of frameworks for EMS development and cross-functional interaction.

Exploring unresolved issues involves further testing of relationships between the amount of exporting in general, and the amount of exporting to the European Union specifically, to the development of an EMS. Other unresolved issues include a better understanding of the amount of sales a firm has to its end customer, and the impact of different types of ownership on EMS development. Additionally, the impacts of external sources of uncertainty on internal uncertainty will be explored through a competing models approach. Addressing the external impacts on EMS will explore the strategic aspects of the research and test support theories such as structure-conduct-performance, and resource based view of the firm. Finally, future investigation will include the expansion of the environmental manufacturing practices construct to include more manifest variables and a testing of this constructs relationship to operations performance.

Exploring strategic verses, tactical, or operational impacts of EMS will provide interesting insight and theoretical linkages to the structure-conduct-performance, resource based view of the firm, and corporate social performance paradigms. Empirical analysis and testing can develop a more consistent theory of EMSs and the impact of these systems at the plant level. Future analysis will involve the use of single industry analysis to highlight gaps between firms considered environmental innovators, and laggards (Sroufe, Curkovic, Montabon, and Melnyk 2000). Additional strategic, tactical, and operational analysis will separate out single levels of management and test for the presence of any bias, or gaps between management levels.

The increased attention on the environment and certification of EMSs as part of supply chain management in the automotive industry (Daniels 2000) has brought about a unique opportunity for research. Empirical examination is called for to understand the impact of customers and compliance on the development of EMSs. To date, most of the literature on environmental business practices and EMSs has focused on compliance driven motivations. The results of this dissertation demonstrate non-compliance incentives for firms to develop EMSs. Future research efforts involve identifying and examining the types of firms involved with EMSs and dissemination of information regarding exemplars, laggards, and the capabilities that separate customer driven from compliance driven firms. The insights gained from these findings will help explain and predict current practices, while also guiding manufacturing plants in decision making and resource allocation. For those firms already engaged in EMS activities, the results of this type of analysis can be used for comparison to existing practices, or benchmarking against exemplars in the field.

Omitted variable can be a persistent problem in developing new fields of research. While researchers strive to obtain as much information as possible, limited resources constrain our ability to explain and predict all that we would like to. Future research efforts will strive to identify and empirically examine new variables and constructs that impact the already dynamic environment surrounding EMSs.

With the increased interest in metrics of all kinds, investigation of environmental metrics may be an untapped resource for gaining an understanding of how processes, people, and products are measured, monitored and managed. A better understanding if environmental metrics also lends itself well to the development of a module for

Enterprises Resource Planning (ERP) systems. To date, ERP systems have overlooked EMSs involvement in enterprise management, and planning.

Future research will also include a longitudinal investigation of the results of this dissertation. A collaborative effort to mail the survey to countries other than the Unites States and a follow-up mailing in North America will provide valuable insights not obtainable in a static look at EMS development. There is a tremendous opportunity to expand this research to develop longitudinal examination, and international analysis and comparison.

Finally, theory building can be extended to the integration of several other information systems. EMSs and information systems are part of TQM (Curkovic 1998), new product design and Design for the Environment (Sroufe, Curkovic, Montabon, and Melnyk 2000). The evolution of MRP systems to include environmental information has already been demonstrated (Melnyk, Sroufe, Montabon, and Calantone 1999). EMSs can also be extended to become integrated into activity based costing and accounting systems. Of additional interest to researchers is the extension of EMSs as an Enterprise Resource Planning (ERP) module, or as a means to capture, monitor, and report environmental metrics at all levels of the manufacturing plant.

5.8 Concluding Comments

EMS theory development is very new and still developing. A large theoretical model hypothesized the relationships between seven constructs and fifty-six variables. Testing this large structural equation model required a large-scale survey and resulting sample size, field studies, and a substantial amount of underlying theory. Given the dearth of existing environmental theory, this dissertation drew theoretical underpinnings from prior experience of the researcher, ongoing research projects with the National Science Foundation, the American Production and Inventory Control Society, the National Association of Production Management, and prior empirical and normative research. The results indicate the emergence of a valid and reliable EMS construct and the impact of this constuct on operations performance.

This EMS construct can be considered a new, but overlooked capability of operations management. Overlooked because typically little is known about these systems despite international standards and the fact that environmental systems in the form of Environmental Health and Safety, have been around for some time. The focus of this dissertation is to define and bring about a better understanding the impacts of an EMS on operations performance. Additional insight reveals that EMSs have both direct and indirect impacts on operations performance. Indirect impacts are shown through environmental design, manufacturing, and waste practices. These constructs contain several specific practices a manufacturing plant can be involved in, and how these practices in the form of a summated scale impact operations performance.

The results of the dissertation help to clarify some of the confusion surrounding environmental business practices and EMSs. This is accomplished by identifying a new construct for the operations management field and developing untested relationships between this new construct, sources of internal and external uncertainty, firm effect variables, environmental practices, and finally operations performance. The findings indicate that firms with a well-developed EMS have the potential to positively impact plant performance in the form of quality, cost, and lead-time, while simultaneously improving firm image and position in the marketplace.

Appendices

APPENDIX 1 CONSTRUCTS AND MEASURES

Sources of Internal Uncertainty

- Cobehav: top management behavior
- Coposture: company decision making
- Plrisk: amount of risk taking
- Plidea: executives use idea people
- Plcomp: dealing with competition
- Plchange: rate of change in production
- Conew: rate of new products

Sources of External Uncertainty

- Coobso: rate of obsolete products
- Cotech: change in technology
- Cotaste: demand is easy to predict
- Coprod: prediction of competitors
- Comark: changes in marketing
- Plsit1: external environment has little threat to survival of firm
- Plsit2: the external environment is rich in investment and marketing opportunities
- Cosit: can control and manipulate external environment

EMS Development

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

Design Practices

- Optproc: process redesign
- Optprod: product redesign
- Optreduce: reduce
- Optsub: substitution
- Optrepck: returnable packaging
- Optproln: prolong use
- Optreloc: relocation
- Optspred: spreading risk

Manufacturing Practices

- Optreman: remanufacture
- Optrebld: rebuild
- Optdis: disassembly
- Optrecycle: recycle

Waste Practices

- Optseg; waste segregation
- Optcreat: creating a market for waste products
- Optall: alliances with suppliers or customers to address env. problems
- Optconsm: consume internally

APPENDIX 1 CONSTRUCTS AND MEASURES CONTINUED

Operations Performance (environmental activities have:)

- Actqual: significantly improved quality
- Actlt: significantly reduced lead times
- Actcost: significantly reduces costs
- Actbene: benefits outweigh costs
- Actpos: improved position in marketplace
- Actadvrs: not adversely affected company position in marketplace
- Actrep: enhanced reputation
- Actprods: design/develop better products
- Actwprod: reduces waste in production processes
- Actwequip: reduced waste within equipment selection
- Actalt: caused company to investigate alternative technologies
- Actinter: improved changes of selling products in international markets
- Actis: reasonable demands on IS and data requirement
- Actaccpt: not compromised products acceptability by customer

APPENDIX 2 FINAL CONSTRUCTS AND MEASURES

(F1) Sources of Internal Uncertainty

- Cobehav: top management behavior
- Coposture: company decision making
- Plrisk: amount of risk taking
- Plidea: executives use idea people
- Plcomp: dealing with competition
- Plchange: rate of change in production
- Conew: rate of new products

(F2) Sources of External Uncertainty

- Coobso: rate of obsolete products
- Cotech: change in technology
- Cotaste: demand is easy to predict
- Coprod: prediction of competitors
- Comark: changes in marketing
- ⇏ Plsit1: external environment has little threat to survival of firm
- ⇏ Plsit2: the external environment is rich in investment and marketing opportunities
- ⇏ Cosit: can control and manipulate external environment

(F3) EMS Development

- 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

(F4) Design Practices

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

(F5) Waste Practices

- Optseg; waste segregation
- Optcreat: creating a market for waste products
- Optreloc: relocation
- Optall: alliances with suppliers or customers to address env. problems
- Optspred: spreading risk
- Optrepck: returnable packaging

(F6) Manufacturing Practices

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

APPENDIX 2 FINAL CONSTRUCTS AND MEASURES CONTINUED

(F7) Operations Performance (environmental activities have:)

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

⇏ Actaccpt: not compromised products acceptability by customer

⇏ Actadvrs: not adversely affected company position in marketplace

⇏ Actrep: enhanced reputation

⇏ Actalt: caused company to investigate alternative technologies

APPENDIX 3 SUMMARY OF FIELD STUDIES

Firm A
Will not Pursue EMS Certification unless it is Mandated by Customers

This privately owned firm is located in Ludington, Michigan. Firm A employees 250 people with only three people in the environmental division. This firm does not export its product and therefore does not conduct business in Europe.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

Fimr A has a very informal system. This manager is consulted on a regular basis concerning environmental issues. These issues typically involve the planning stages for new processes and capital budgeting. This manager's understanding of EMS is general in nature.

This firm has just completed ISO 9000 and does not want EMS certification. They will not go for certification voluntarily, but will do it if the automotive industry says they have to. This decision on EMS certification was arrived at through taking into consideration their available resources. The decision-makers are the CEO, VPs, and owners. External company image is important.

How do you measure performance in your department/area?

Within the environmental department they are measured by the number of complaints (public, state, and federal). Other departments are not directly effected. There are some indirect effects when it comes to product substitution. While they do not formally promote this approach, new products are looked at to assess feasibility. While they are assessing new product and process ideas, environmental issues may come into play, but no one outside of the environmental department has environmental performance measures.

Lessons Learned:

- Very informal EMS.
- Exposure and knowledge of EMS is limited and benefits are only perceived as improved company image.
- Environmental issues seem to be limited to new process design and engineering.
- Within the environmental department performance involves reactive measures such as the number of environmental complaints (public, state, and federal). No one outside of the environmental department has environmental performance measures.

Firm B
Will not Pursue EMS Certification unless it is Mandated by Customers

Located in Warren, Michigan this firm employs 145 people at this UAW facility. There is no environmental staff. This firm is publicly traded and exports about twelve percent of their products, with very little (less than one percent) going to Europe, and less than one percent of sales to the parts, (end user) market.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

This firm does not seem to understand the concept of an EMS. The "system" in place is that of a ground water run-off procedures, EPA and OSHA labeling and MSDS sheet availability, dikes near petroleum products, and annual permits. While these examples of documentation and procedures are attributes of a system, there is no formal system in place.

The actual IS consists of a human resources clerical person who handles the IS components, and acts as a coordinator/organizer for anything that can be seen as environmental. Contracting has a person specifically responsible for State and Federal permits.

How do you measure performance in your department/area?

Productivity: efficiency and piece per man-hour, scrap, and uptime verses available time. This firm does not track outbound wastes. They recycle the steel scrap. Outside of the scrap, this firm only has one dumpster that is taken to a landfill periodically. This could be easily captured with the existing system if they needed to.

Relevance to Dissertation:

- Most of the EMS stuff is perceived as an OSHA and EPA compliance issue.
- The handling of hazardous materials is something they want to avoid at all costs. It is important to have a safe and clean working environment.
- Pollution is an expensive form of mis-management that they feel is already under control.

Firm C
Evaluating EMS Certification

This firm is located in Zeeland, Michigan and employs 2,500 people locally and 7,500 globally. Firm C is a publicly traded company known for environmental awards and practices within the office furniture industry.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

The environmental system is made of the professionals at this firm and their given responsibilities. At the top level, firm C has a corporate steering committee that sets policy. Next, teams implement the projects and policy. Communication within the network of professionals is facilitated through the use of Lotus Notes.

Based on past history, they believe the environmental program is already very strong.

How do you measure performance in your department/area?

They have about four "output" measures. They track "total wastes" in the form of recycling, #s sent to an energy center to generate steam and energy, land fill, and #s of saw dust sent to Consumers Energy Company to generate energy for the local community. In the end of October, 1998, the number of measures was expected to double to 8 or 9.

Hurdle rates for investing in projects are lower for environmental initiatives. Economic Value Added is often used to evaluate projects and report results of projects. It was noted that there are no EVA projects that do not impact the environment.

Relevance to Dissertation:

- The environmental system is made of the individual professionals at this firm.
- EMS certification and standards may help with documentation and follow-up of projects.
- At the time of the interview, firm C was conducting a gap analysis to determine what part of their processes can be improved. EMS certification should add structure to the existing environmental and manufacturing systems if the are going to consider integrating it into the existing system.
- Hurdle rates for investing in projects are lower for environmental initiatives.
- Eco metrics is in its infancy: Economic Value Added could be used to develop a good Eco measure.
- They have always had CEO commitment to the environment.
- Track "total wastes" in the form of recycling, #s sent to an energy center to generate steam and energy, land fill, and #s of saw dust sent to Consumers Energy Company to generate energy for the local community.

Firm D
Evaluating EMS Certification

This Michigan based pharmaceutical firm is publicly traded and employees 6,000 people locally. Its products are sold in the European Union and internationally.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

Environmental Safety and Management System (ESMS). The respondent claims that "too many people separate environment and safety," This firm wanted the system to cover safety too. Their goal is to have a consistent approach, standards, and focus efforts toward continuous improvement. They want to collect data for benchmarking and incremental improvement. In 1998, all sites were asked to implement this system, no deadline is in place. This firm has 40 facilities worldwide, each of these facilities will adopt the ESMS in time.

How do you measure performance in your department/area?

This is the second year for their annual Environmental Report. This report and the environmental efforts of the firm have the endorsement of the CEO. This report also states that the ESMS will be the conduit for the tracking and reporting of the performance measures. They mostly try to look at end points, or output measures. (e.g. total waste, energy consumption, VOC levels, hazardous materials, non-hazardous materials, water, air emissions beyond SARA reportables, and accident rates.

Relevance to Dissertation:

- Focus on output metrics
- Their goal is to have a consistent approach, standards, and focus efforts toward continuous improvement through the use of the Environmental Safety and Management System (ESMS).
- Corporate culture of environmental responsibility and a strong commitment to the environment are major factors in environmental initiatives.
- A Belgium facility will be the first EMS certified site. They claim this is due largely to cultural influences in Belgium.
- Most important benefit of environmental efforts is better protection of the environment for future generations (sustainable development). Improved image, prevention of environmental liabilities, saving money, improving cost structure, and source reduction are all potential benefits.
- Environmental image is important.

Firm E
Pilot plant for EMS Certification for North American Operations

Located in Clinton, Michigan, firm E employees 300 people at this facility. This firm is a tier I supplier to the automotive industry. There is one environmental manager for this facility. This manager is also responsible for quality. This is a publicly traded company owned by a firm headquartered in St. Ellens, England. The parent company is the largest glass company in the world. They sell to the aftermarket division within their company but not to the aftermarket directly. This plant does not have any European business, but they do have customers in Mexico and Venezuela.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

Their EMS uses/mirrors their QS 9000 system. The respondent is both the quality and environmental manager. He used his experiences from the QS 9000 certification process to develop their EMS, which resembles QS 9000 in structure. This manager performed a gap analysis that allowed them to determine that this facility is meeting 70% of the EMS certification requirements. They were lacking the corporate environmental procedures at the time of the interview. These procedures help to integrate processes.

They were almost ready for EMS certification at the plant level. However, they are not ready at the corporate level. Their EMS is open to the entire company and is on-line. Information, procedures and work instructions on EMS issues are available to everyone via computer database, but goals and performance issues are not available. This database is even accessible from the shop floor via a touch screen information system.

QS 9000 was used as the template for the EMS. Considering this manager is both the quality and environmental manager at the plant, the progressive ISO approach is logical. This is the only plant where the quality and Env. Mgr. is the same person. It was a huge benefit in developing the plant's EMS and gearing up for EMS certification. They were registered for EMS certification by the end of 1998, but awaiting corporate support for the effort.

The EMS system is perceived as just another management system, which focuses on environmental issues rather than quality issues. This plant has an environmental policy in place, but it is not EMS certification compliant because this policy does not say anything about the community.

Performance measures:

Quarterly corporate statistics – baseline information such as number of periods, environmental costs, amount of energy (gas and electric), trash waste, hazardous waste, how much recycled, non hazardous waste. A responsibility of the managers is to make sure that the quality and environmental goals do not conflict. In the long-term they do not conflict and support each other, but in the short term they might conflict with one another.

Relevance to Dissertation:

- The "European" way of thinking is to be more environmentally conscious. The Europeans are much more caught up in the EMS standards.
- Their EMS uses/mirrors their QS 9000 system. Their EMS is open to the entire company and is on-line. Information, procedures and work instructions on EMS issues are available to everyone via computer database. This database is even accessible from the shop floor via a touch screen information system.
- This manager has to make sure that the quality and environmental goals do not conflict.

Firm F
Pilot plant for ISO 14000 Certification for North American Operations

This is a privately owned foreign subsidiary in St. Joseph, Michigan. There are approximately 1300 employees at this UAW facility. Including the Environmental manager, there are only four people in the environmental division. Only a small percentage of sales are exported. Most of their sales are to OEMs with some after market sales. This is a Superfund site and dealing with Superfund regulations is a big project.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

The Manager, of Health, Safety, and Environmental Quality has three Env. staff. This department operates in isolation from the rest of the company. The Env. group does work with the quality group to learn from their experiences with the QS 9000 certification process. In the past their EMS was compliance driven and not document driven.

The new system is an extension of the QS 9000 system. At the time of the interview, the EMS group was still collecting information such as process flow analysis and costs of waste. The group started by reviewing the site's compliance history, and looking for current environmental problems. They have used the services of consultants to perform a gap analysis of their EMS system and processes. Firm F realized from the gap analysis that there were many opportunities for improvement. Their EMS has had no impact of the execution of shop floor activities at this time.

Firm F appears to have a good understanding of EMS certification guidelines. They were ready for EMS certification in October, 1998. Their corporate staff in Illinois gave this plant the go ahead to implement the EMS system and this plant is the pilot site for North American Operations. The corporate staff will use this site to determine whether the process is cost effective.

All of this firm's European plants were Eco Management and Audit Scheme (EMAS) certified so they wanted to try something similar in North America.
A major goal of the ERM staff is to shift ERM responsibility from the ERM staff to others such as people on the shop floor. This is one of his major challenges because right now all Environmental issues fall on the ERM staff.

How do you measure performance in your department/area?

No environmental metrics are used, instead they tend to look at end-of-pipe, or output measures of waste. The environmental department is pushing hard to change this because they feel it would help to make them more effective. Environmental costs are not included in the decision-making process for capital investments. This manager could easily incorporate environmental issues into the decision-making process because he is getting a better idea of what the costs will be. However, it is not a part of the mindset of the company to include these costs into the process. Therefore, the environmental implications of decisions are not considered which contributes to the compliance/reactive approach that surrounds the environmental department.

Half of this manager's work is environmental, yet he is not evaluated on it. By taking a "management by fact" approach, the EMS group is able to track waste levels and have some metrics for decision support. What they are coming to realize is that there are many hidden costs that before were considered a cost of doing business.

Relevance to Dissertation:

- The EMS system is an extension of the QS 9000 system.
- EMS has no impact on SFS activities
- Foreign plants have certified EMSs so they want to do this in their US facilities.
- Metrics are end-of-pipe, or waste output measures
- They tend to have a reactive approach to environmental decisions
- After capturing data and quantitatively looking at environmental issues, the EMS group can show they are a benefit and not a cost to the organization. What they are coming to realize is that there are many hidden costs that before were considered a cost of doing business.

Firm G
Pursuing EMS Certification

Firm G is a privately owned company located in Holland, Michigan. They employ 2500 people in western Michigan. There is one corporate environmental manager and ten people comprising the environmental staff at the Holland facility. They also have manufacturing and sales office facilities in Kentucky, Arizona, Mexico, three in China, in Malaysia, a plant in Flint, three in Thailand, Portugal, Scotland, Germany, and Spain. Approximately 10% of sales are in exports, and only half of one percent of sales go to the replacement part market. The parts made in the Michigan plants typically do not go to

Europe since they already have plants located in several countries there.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

The managers interviewed describe a long history of being environmentally friendly. They are trying to make their suppliers greener but, as of 1998, this process is in the infancy stages. Donnelley encourages EMS certification of their suppliers, if they are not certified, they should at least be compliant.

Firm G appears to have a good understanding of EMS. EMS and safety issues are a very formal and standardized part of the new product development process (they call it PMP). Next, concept development fully begins, and they enter the design phase at some point a BOM is generated, and the product manager then submits a PMP to the Corporate manager of Safety and Environmental Strategy. This manager will examine a number of EMS issues associated with the PMP (e.g., air permit requirements). This manager can prevent a product from going through development if the EMS issues are severe enough

Formal EMS documentation has started with policies and procedures at level one and environmental management procedures at level two. The environment has always been a part of their culture, which was engrained by the founding owner.

The CEO made a trip to Europe to visit their facilities there and saw the plants there being pressured by customers to pursue EMS certification, and then made it a corporate priority. Their customers in Europe include Rover, Vauxhall, Opel, and Volvo. These companies placed pressure on the firm's European facilities to become EMS certified.

The company has a long history of top management commitment to ERM. This environmental manager has never turned down for ERM project funding. The environmental manager does not know what the costs of formalizing their EMS will be in dollars. Interestingly, any environmentally related investments made do not have to be justified from a cost/benefit perspective. They are environmentally proactive and address environmental issues early on in the product development process before the launch actually occurs.

External pressures have shown no formal interest from this firms North American customers to pursue EMS certification. One of the big three automotive OEMs have offered some verbal encouragement.

A strict and formalized EMS procedure reduces waste itself because it sends up red flags and identifies opportunities for improvement. Improvement comes from measurement and identification. They have reduced variation and product yield and process yields have improved. Another benefit includes the prevention of pollution. The records created by formalizing their EMS identify spikes and opportunities for improvement. Their experiences with QS 9000 helped them with ISO 14000, it kept costs down and increased their likelihood of implementation success.

How do you measure performance in your department/area?

The EMS certification process benefited them mostly because even though they previously had a formalized EMS system, they did not have documented targets. Because of EMS certification, they have started to establish more key measures, that were previously overlooked. Energy consumption will be considered in the future. For

Operations Management: Safety, quality, production, moral, delivery, noncompliance. For the Environmental Manager: Service provided to various units. Most people set their own goals with supervisors and are measured against these goals. Corporate measures include: goals established with the supervisor, management plan, action plans, and goals.

Relevance to Dissertation:

- The EMS certification process started at this facility was influenced by their European firms. Their plants in Europe were being pressured by customers to pursue EMS certification. In the US, some automotive OEMs have only verbally questioning suppliers about EMS certification.
- Formalizing their EMS and preparing for EMS certification was simplified because of the QS 9000 experiences. Their experiences with QS 9000 helped them with EMS certification, it kept their costs down. Benefits stress the importance of formalizing processes and documentation.
- They have a strong corporate culture. The company has a long history of top management commitment to the environment.
- Documentation is important to insure that in the absence of a key person, they can at least find a paper trail and procedures and policies to continue operations. Their EMS is currently on-line for all functions to access.
- Environmentally related investments are justified using less restrictive cost/benefit thresholds.
- There is a very strong commitment to the environment. This commitment is so strong that they some times do not measure the costs, or the financial benefits.
- Stress output measures such as energy consumption, quality, safety, and non compliance.

Firm H
Goal: First US GM Plant to Obtain EMS Certification.

Firm H is a publicly owned, Tier I automotive supplier in Grand Rapids Michigan. This firm is owned by one of the big three and has approximately 1200 employees at this facility. There are only three people on the environmental staff. About 30% of sales are exports, no sales to Europe, and approximately 10% of sales attributable to after market replacement parts.

What type of environmental system is in place, and what is its role in the planning and execution activities of the firm?

The EMS is patterned after the ISO 14000 standards. They completed three EMS audits by November 1998. This firm appears to have a very good understanding of EMS certification. There is an EMS system is in place. Firm H was the first Michigan plant given the Clean Corporate Citizen award. The award requires communication with the public the results of environmental efforts, and make policies public. The EMS system helps to show their environmental consciousness. Environmental awards are considered very good for public relations and positive company image.

The manager of Environmental Systems is the environmental champion in charge of making EMS certification a reality. There is a green corporate culture.

How do you measure performance in your department/area?

Basically, there is a team-oriented approach. There are different groups involved; product line divisions, lifters (the part), manufacturing services, and support groups such as environmental and chemical management. All groups are challenged to reduce energy, costs, and waste. They are typically measured by meeting goals, and the importance (size, scope) of the projects underway. An example may be a goal of 10% reduction in waste, you are measured on how well you are doing in meeting that goal in a certain area or process.

The environmental department is also part of the plant engineering function. This makes it a little easier to find opportunities so save energy. The engineers can better design processes with lower energy requirements. In 1997, they really started to push for environmental improvements. In 1996 they made a 29% reduction in waste, and a 14.9% reduction in energy reduction (these numbers are volume adjusted). Since 1993, they have eliminated 11 waste streams. They now only have one waste stream left to deal with.

Relevance to Dissertation:

- They want a system that works and from which they can benefit from financially. They looked at the system, recorded what they have and what they need. Next they asked the question "what will this do for us?", while considering the cost savings involved. They plan on combining quality and EMS certification.
- Report waste output measures to external stakeholders.
- Seek to reduce energy, costs, and waste metrics.
- Top management support is essential to successful implementation.
- Environmental awards and EMS certification are considered important for good public relations.

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