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DISSERTATION

ENVIRONMENTAL DECISION MAKING:

COMBINING ENGINEERING AND BUSINESS ASPECTS

David R. Stewart

Department of Civil Engineering

In partial fulfillment of the requirements

For the Degree of Doctorate of Philosophy

Colorado State University

Fort Collins, Colorado

Summer, 2000

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Colorado State University July 10, 2000

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Committee on Graduate Work

Advisor

Co-Advisor

Department Head/Director

ABSTRACT OF DISSERTATION

ENVIRONMENTAL DECISION MAKING:

COMBINING ENGINEERING AND BUSINESS ASPECTS

This dissertation provides a new method of making environmental decisions by combining engineering and business aspects. Companies in the future will be looking for methods that provide for sustainable development. This dissertation provides decision makers within companies the ability to utilize the Stewart Environmental Management (SEM) decision support system. The original data from this dissertation was developed through a Mini-Delphi survey of 11 experts. The Mini-Delphi provided current and future thoughts of these experts regarding environmental management systems and how decisions concerning the environment are made in companies. From the Mini-Delphi data, a decision support system was developed. The first aspect of the SEM decision support system is the utilization of the environmental management matrix. This matrix requires that a company consider its relative position between the perceived position of compliance, ranging from non-compliance to industry leader, with several aspects such as environmental posture, regulatory attitude and others. Once the company decides its relative position, then the collective knowledge base will determine how to interact with the perceived environmental problems. The decision support system combines the engineering, financial and marketing

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aspects of the company into one collective knowledge base. This collective knowledge base interprets the environmental problem and then utilizes an expert naturalistic decision making system to provide for an alternative. The alternative is implemented and a feedback loop is provided to constantly improve on the selected alternative.

The SEM is an improvement over traditional decision support systems because it is a system that identifies and provides a dynamic method of environmental decisions by combining the engineering and business aspects within a company. Future research of this topic will include further studies on the effectiveness of the SEM decision support system.

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CHAPTER ONE

INTRODUCTION

1.0 Background

One of the greatest challenges facing society today is to meet human needs through the productive capacity of industry and, at the same time, to sustain the environment. The dilemma is that if industry is unregulated, the environment is harmed, but if regulations are excessive, then industry and the economy suffer.

There is evidence that regulations are not leading to cost effective pollution control. For example, the cost of environmental compliance at 18 different superfund sites for various companies has risen from 3% of their total gross revenue in the 1970's to more than 20% in the 1990's (Dixon, et al., 1993). A survey of 29 companies in the late 1970's and early 1980's has shown a similar increase in the cost of environmental compliance (Sarokin, et al., 1985). At the present time, the cost of environmental compliance is over 2% of Gross Domestic Product (Dale, 1999).

These increases in environmental management costs lead naturally to a desire by industry to pursue the integration of compliance with environmental regulations, environmental systems management, and the overall company

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management system, with an eye on the bottom line. This goal—integration of environmental management and financial management—is the core issue addressed by this dissertation.

Companies need to bridge the gap between their current management scheme and an integrated management scheme utilizing a Decision Support System (DSS) approach that integrates the corporate, engineering, financial, and marketing goals of the company as well as incorporating the necessary environmental responsibilities.

Corporate leaders are calling for such a system. For example, this change in attitude about environmental management for companies is described by Tom Zosel of 3M Companies (Resource@ 1999).

> *"As we go into the 21st century, sustainability is going to be a competitive advantage... We need to focus on how to make sure that before the 21st century rolls around, the United States has a green plan, on how it is going to [comprehensively] address issues like global warming, the endocrine disruptor concern, smog, clean water, and so on."*

The current approach toward enforcing environmental regulations is based on a command and control system where government regulates with little attention to

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corporate goals (Ruckelshaus, 1997a). This paradigm of "command and control" focuses on societal objectives, especially representing traditional models or power structures; companies now need to participate in environmental control and compliance for both financial and environmental reasons. This will be required due to the economics of the business community, the cost of environmental compliance and the concept of sustainable development. Sustainable development in this dissertation will be defined as the process to make products or provide services with fewer critical resources, release fewer contaminants, contain less toxics, and make products that can be recycled, but offer the same quality at an equal or lower cost (Wallace, 2000).

The paradigm shift of companies participating in environmental control and sustainable development will require that companies provide a balance between societal and corporate risk. Corporate risk is defined as the minimization of exposure through the efforts of management to add to shareholder value. Many companies are reluctant to try innovative techniques for environmental projects due to the potential for failure and an increase in financial liability. Categories of corporate risks that are addressed in this dissertation include:

1. Environmental risk: This is the risk of the company's activities affecting the environment through discharges to the air, water or land.

2. Business risk: This is a risk that the business assumes with any product or project. This risk is normally associated with the failure of the process/project or the financial liability that leads to reduced profitability.
3. Personal risk: This is the risk of the environmental manager or employees of the company. This risk is associated with environmental laws, which, when broken, can result in personal, civil and criminal liability.

Throughout this dissertation, each type of risk will be identified or, if all three risks are being discussed, they will be referred to as collective risk.

In addition to companies not willing to take the above collective risk, they do not have a satisfactory accounting method for tracking environmental costs. Therefore, the paradigm shift discussed above must be accompanied by proper data on which to base decisions.

Thus, total integration will be achieved through a new risk-based Decision Support System to assist management with environmental decisions.

This new Decision Support System will work within the framework of market driven environmental regulations, such as in California, where companies are required under Proposition 65 to determine the toxicity of their products and inform the public regarding this toxicity. This California law substantially

increases what is currently required on a national level by the Toxic Substances Control Act (TSCA) or the Federal Insecticide, Fungicide and Rodentcide Act (FIFRA). Proposition 65 has encouraged industry in California to provide more nontoxic products to the consumer market, which in turn is increasing the industries' environmental awareness (Becker. 1996). For example, if a company has determined that environmental values are important, then meeting the requirements of Proposition 65 will already be incorporated into the overall company management system.

The main problem industry faces is changing their approach toward environmental compliance. *To address this, the integration of environmental and business aspects must come through a new approach – one which focuses on corporate core values as well as profit motive.*

A company that has visionary core values is one which has as one of its goals profit; however, this goal is one of many. Other goals would include compliance with environmental regulations, providing a quality product or maximizing the stockholders' interests, broadly stated. In several studies of visionary companies, it has been shown that the most successful of these companies have a set of core values which leads them to a totally integrated approach to management (Brown, 1992; Cobb, 1992; Macauley, 1992). These core ideals

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are based on the work by Collins and include the following four statements (Collins, et al., 1994):

Core Values: *The organization's essential and enduring tenets* – a small set of guiding principles; not to be confused with specific cultural or operating practices; not to be compromised for financial gain or short-term expediency.

Core Purpose: *The organization's fundamental reasons for existence beyond just making money* – a perpetual guiding star on the horizon; not to be confused with specific goals or business strategies.

BHAG's: *The organization's Big Hairy Audacious Goals* – these are goals that the organization is not currently capable of meeting at the time of setting the goal. This type of goal will take 10 to 30 years to reach.

Company Vision: *When the organization sets the BHAG's, they will have a very specific vision of what the company will be like when it achieves this goal* – this company vision should not be confused with Core Ideology. The Core Ideology equals the combination of the Core Values and the Core Purpose. This Core Ideology is

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something that the company attempts to reach, but which is not attainable. The company vision referenced above is something that is obtainable, while the core ideology is an ideal that can never be reached.

All of the above elements have some type of environmental focus. However, only one element of the core ideals, the core values, is specifically focused on the environment The core values are one of many elements that focus on the company's efforts to respond to complementing business and financial matters with the environment. Companies are beginning to view the environment with a long-term approach and understand that the regulations provide only the foundation for environmental management, and that their core values will provide the additional basis upon which to manage the company's environmental matters.

1.1 Motivation for Decision Support System

Companies, however, will not make this shift to a core value system because they are "basically good," but rather they will make the shift from a regulation-driven minimal environmental management system because of *a competitive advantage, public image, return on investment, market share and strategy,*

reduction of enforcement activities by a regulatory agency, and EPA allowance of certain activities without a permit, such as those proposed by the Common Sense Initiative (EPA @ common sense, 1999; National Metal @, 1999). Therefore, it is important in this research to determine how business and environmental managers make decisions regarding environmental management systems.

How does a company shift from the regulatory environment to the core values environment? First, the company must decide which core values it wants to follow and promote. Second, the stakeholders or investors need to approve and agree with these core values. Third, the company must consider the financial aspects. Will a shift from compliance with only environmental regulations to core values that include environmental aspects add to the bottom line? Because profitability and return on investment to stockholders are major concerns for companies, managers will need to include a more holistic approach when shifting from a regulatory environment to a core values environment. This will include life-cycle costs, costs for public image and other intangible costs. If this conversion provides a positive return, then the company should proceed. If a positive return cannot be achieved, then a decision must be made by the management team to evaluate the minimum level of actions that will be required by the government and then implement those decisions.

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The final step would be total implementation of the environmental management system throughout the company. This approach has been proven to be successful in several American companies, such as the American subsidiaries of Honda and Toyota (Maxwell, et al., 1998). Companies need a new method of making decisions regarding the environment. Numerous companies, which are considered leaders in environmental matters, have a method of making environmental decisions. Research will help determine how these decisions are being made and why. Research is also needed to help determine if these companies are incorporating an environmental management system into the overall management system.

When companies shift from a regulatory driven management approach and move toward an integrated approach of core values for environmental management systems, they will require information and the proper techniques for the decision making process. This decision making process will include information on how to make environmental choices and decisions in a particular business setting. Research is needed that will provide information as to how these decisions can be made while maintaining the profitability of the company.

In summary, reasons for utilizing the Decision Support System are reduction of enforcement activities/regulatory relief, EPA allowance of activities without a

permit, competitive advantage, public image, market share and strategy, and return on investment.

There will be several requirements for implementing a decision support system. It must enable the company to decide and the stakeholders to approve core values. Managers must be able to develop a holistic approach, including life-cycle costs, costs for public image and other intangible costs. The company must consider financial aspects, as well as engineering and marketing aspects. Managers must organize information and techniques for the decision making process and the environmental management system must be implemented throughout the company.

1.2 The Research

Because the Decision Support System accounts for the engineering and business aspects of the company, the environmental manager and engineer must use it to review complex questions that include collective risk analysis; legal, regulatory, business, financial and engineering aspects of the company; and ethics. Effects of a wrong environmental decision are critical ethical matters. For example, the environmental manager might make decisions that can affect future generations through negative health effects to employees caused by chemicals utilized at a facility. A wrong decision or one that does not take into

account all of the critical aspects can lead to severe consequences in the future, both for the company as well as the individual.

The decision process will require working with corporate management to make choices in the following areas:

- **Identification of the Environmental Problem:** Identification of the environmental problem within a changing business setting and communication to the business manager.
- **Daily Operations:** Areas of environmental management that require attention on a daily basis.
- **Decision Making Process:** Evaluation of the processes, management systems, costs, ethics, etc., caused by various decisions in order for the company to lower the overall collective risk and costs of environmental operations.
- **Regulatory Environment:** Costs and potential opportunities associated with new or existing regulations. The environmental engineer will also need to help develop innovative methods of making decisions within the guidelines of these regulations to lower overall risks and future costs.
- **Company Management System:** Environmental management system within the company's strategic management planning process

Figure 1.1 provides a depiction of this process:

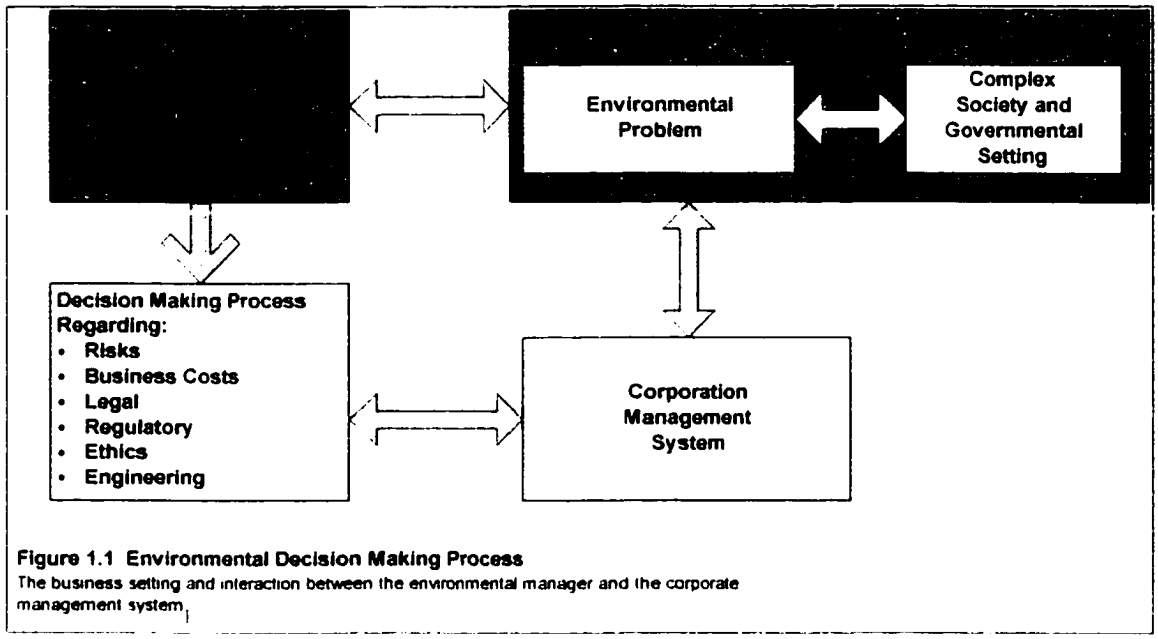

Figure 1.1 Environmental Decision Making Process
The business setting and interaction between the environmental manager and the corporate management system.

A business setting is defined by combining the environmental problem and its interaction with complex society and governmental settings as shown in Figure 1.1. To address the environmental problem, the corporate management system and the environmental manager need to interact to implement the decision making process. The combination of these two entities will be able to address the environmental problem and adjust the solution to the complex business setting.

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1.3 Goals of Dissertation

The need for a Decision Support System to improve corporate decision making about environmental policy is clear and serves as the focus for this dissertation. Based on this need, the goal statement adopted for the dissertation is:

> **Develop a Decision Support System to enable companies to choose environmentally-responsible business strategies that also achieve investment objectives. This Decision Support System should identify engineering and business strategies that yield environmental benefits, optimize investment in environmental expenses and maintain the company's vision.**

Obviously, this will also require the company to attempt a reasonable approximation between the ideal and real situations.

1.4 Research Tasks

The dissertation will be carried out through the accomplishment of the following tasks:

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Literature Review: A literature review will outline the status of risk assessment as it relates to environmental and company management systems. It will also review the status of decision systems that incorporate environmental aspects and coordinate environmental and business Decision Support Systems. Other topics include: environment and business, or how environmental policies are affecting business strategy; how business is responding; status of risk assessment; environmental management and accounting systems; traditional and new forms of Decision Support Systems; the Mini-Delphi method of gathering expert opinion; international trends; and examples of company responses to environmental challenges.

Mini-Delphi Survey: The initial review of the literature detected a lack of information on risk assessment by environmental managers and business owners. There is limited information on how decisions are made during an environmental problem assessment and how these decisions affect the overall business strategy of the company. A Mini-Delphi survey will identify critical items in collective risk assessment and environmental management and provide a perspective on requirements for future development of business. Responses to sustainable development will also be investigated during the Mini-Delphi. Sustainable development will be a difficult task to accomplish for future environmental engineers and managers. Finally, the Mini-Delphi survey will show how environmental managers make decisions that involve environmental

and business aspects and how they expect the decision making process will change in the future. A panel of 15 experts from industry will be utilized in the Mini-Delphi survey.

Development of Decision Support System: The next step is to develop a Decision Support System to achieve the goals outlined above. It is envisioned as a comprehensive chart showing the processes of environmental decision making which will incorporate both business and engineering aspects and allow a company to include environmental aspects and business goals into their strategic planning model. This Decision Support System will include such business aspects as life cycle costs, investor views of environmental issues and product labeling that might change company acceptance in the market place. The Decision Support System will be developed from the literature search, the Mini-Delphi results and the case studies.

Case Studies Regarding Environmental Decision Making: Two brief case studies will provide data from personal interviews of managers and show connections with the Mini-Delphi survey, the Decision Support System and the ability to make better environmental decisions. The case studies will provide a retrospective basis for verification of decision making processes and allow review of the environmental and business aspects of the cases.

Discussion and Conclusions: The survey, Decision Support System and the case studies are intended to provide useful information regarding environmental management systems. The conclusions will summarize what the Decision Support System offers to the field of engineering and how it can be utilized by companies to make better environmental decisions. It will also provide information on how engineers might be trained to make better decisions about environmental management.

1.5 Organization of the Dissertation

This dissertation will be organized as shown in the following figure:

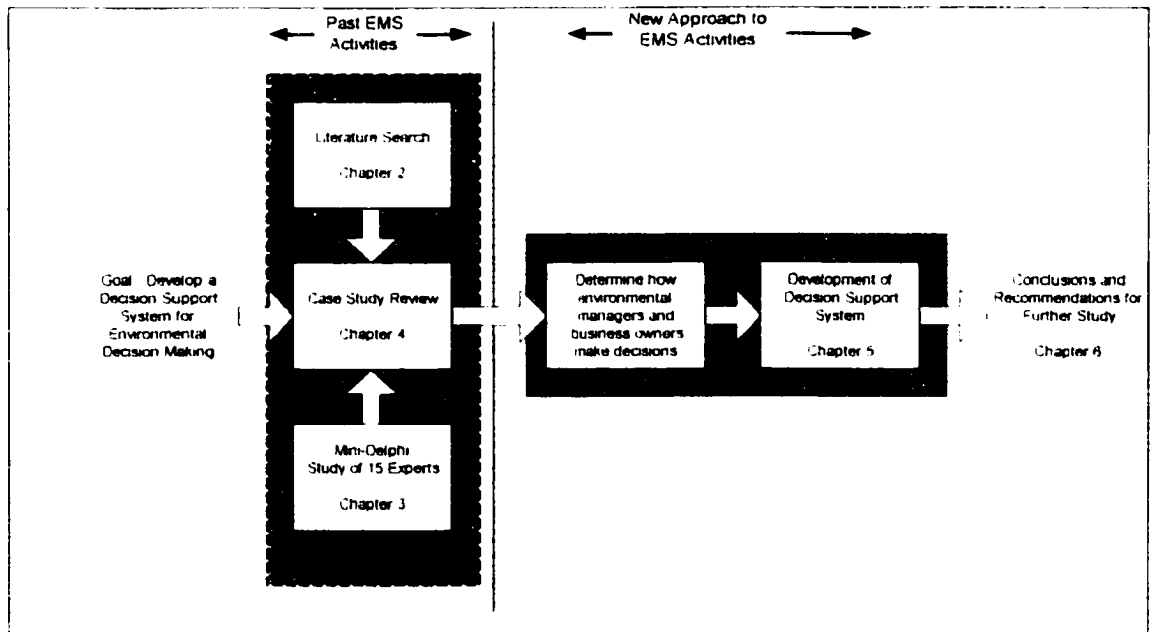

Figure 1.2 Dissertation Organization
The organization of this dissertation for environmental decision making process

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The first chapter provides background information on environmental management systems within companies and establishes the focus of this dissertation, which is to develop a Decision Support System to enable companies to choose environmentally responsible business strategies that also achieve investment objectives. The second chapter reviews the literature regarding types of risk assessments, environmental financial concerns, traditional Decision Support Systems, naturalistic decisions support systems, how the EPA views environmental management systems and several case studies which emphasize the benefits for progressive environmental management systems.

The third chapter provides the methodology of the Mini-Delphi Survey as well as the results of the survey. The actual survey and the compiled answers are provided in Appendix A. This survey will provide information on the current method of decision-making as well as a future perspective in this area. From the information provided by the Mini-Delphi survey, a flow chart will be developed which will be the basis of the Decision Support System for the environmental management system.

The fourth chapter provides two case studies regarding environmental decision-making. This information will be utilized to support the need for business and environmental engineering aspects of the company to work cooperatively in the business setting. These cases are based on published information and the

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writer's experiences working with the firms on environmental management systems.

The Decision Support System presented in Chapter Five will be developed from the literature search. the Mini-Delphi results and the case studies. It moves the traditional model toward more realistic business settings to involve all the factors that affect the environmental manager's decision-making process. This decision support system is entitled the Stewart Environmental Management (SEM) decision support system.

The SEM model will provide the company decision maker the ability to utilize an environmental management matrix to position the company in the future. The company will choose their environmental position and implement the requirements of this position utilizing business aspects such as regulatory attitude, environmental posture, business opportunity, etc. The SEM will then provide the method for combining the engineering, marketing and financial aspects of the company. The combination of these aspects is known as the collective knowledge base. This collective knowledge base will utilize an expert system of naturalistic decision making to provide alternatives and implement the chosen alternative. The SEM then will implement the decision within a dynamic feedback loop that allows for constant improvement on the alternative decision.

The sixth chapter provides conclusions and recommendations for further research.

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CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter seeks to present literature from the different areas that go into the design of the decision support system. These follow the outline below:

- Introduction to the Environment and Business: How the environment affects business has been growing as a topic for over 30 years. This section's review will discuss the history and current view regarding this area of concern.
- Business and the Environment: Business's response to environmental issues; their environmental management systems and financial issues are discussed in this section.
- Risk Assessment and the Business Environment: This section will discuss the different types of risk faced by companies and how risk assessment is conducted. To emphasize why this is important, the US Presidential Commission on Risk Assessment and Risk Management will be discussed.

- Environmental Management and Accounting Systems: This section will cover how companies account for their costs and benefits associated with environmental management systems.
- Traditional Decision Support Systems: This will cover the traditional approach to environmental decision support systems and associated business aspects.
- New Approaches to Decision Support Systems: A new approach to decision support systems, the "naturalistic" approach, will be presented and it will be shown how it applies to environmental engineering.
- Mini-Delphi Method: This section will discuss the Mini-Delphi method of gathering expert opinion and how it relates to the environment.
- Examples of Corporate Environmental Risk Management: Several companies which have incorporated environmental management systems into strategic planning and business decisions will be discussed.
- International Aspects of Risk Management and Business Systems: This section discusses how environmental management systems have expanded internationally.

2.1 The History and Current Status of Business and Environmental Management Systems

Business's response to environmental management and risk assessment is still in an infant stage of development. However, the National Research Council (NRC), the Enterprise for the Environment (E4E) and the American Institute of Chemical Engineers have developed approaches they believe to be valuable in making environmental decisions. These present methodologies for risk assessment, but do not provide much guidance for how companies should integrate risk with business decisions.

Environmental risk assessment was reviewed in the 1982 report by the US National Research Council (NRC) Committee entitled, "Risk and Decision-Making: Perspective and Research," (National Research Council, 1982) and the subsequent report in 1983 entitled, "Risk Assessment in the Federal Government: Managing the Process," (National Research Council, 1983). In these reports, the following steps were discussed:

- **Hazard identification**: The determination of whether a particular chemical is or is not causally linked to particular health effects.

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- **Dose-response assessment**: The determination of the relation between the magnitude of exposure and the probability of occurrence of the health effects in question.
- **Exposure assessment**: The determination of the extent of human exposure before or after application of regulatory controls.
- **Risk characterization**: The description of the nature and often the magnitude of human risk, including attendant uncertainty.

As part of this risk assessment process, the EPA and NRC developed strategies for risk management. Risk management entails determining whether and how risks should be managed or reduced. It is based on the results of the risk assessment as well as other factors (e.g., public health, social and economic factors). Risk management options include pollution prevention or control technologies to reduce or eliminate the pollutant or other stressor on the environment. The environmental or public health impacts resulting from risk management decisions must then be monitored so that any necessary adjustments can be made (EPA, 2000).

In subsequent studies, the EPA spent a considerable amount of time regarding risk estimation and risk evaluation. Risk estimation is the method by which the scientist will determine the amount of risk associated with a particular pollutant. Typically, this will be described in the statistical probability of an individual contracting a certain type of cancer or tumor. The risk evaluation process then

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leads to the certain value or amount of risk that is acceptable. As a follow-up to the previous example, the risk evaluation would determine if one case of cancer in 10,000 or 1,000,000 was the appropriate level (EPA, 1996).

This process of risk assessment deals with health and safety but does not address business issues. However, the NRC does state that the term "risk assessment policy" requires judgment by the risk assessor in setting regulatory policy and recommends that environmental risk assessment be separate and independent from environmental risk management. Environmental risk assessment should only include the four areas listed above, but inherent within the policy setting procedure is the required judgment and choices from the broader social and economic policy issues. Thus, risk assessment does not take into account the ability of the entity, such as a company, to provide the capital for site remediation or environmental management. Also, environmental risk management must consider social and economic aspects.

The many studies of environmental risk assessment since the original work by the NRC tend to be predominately focused on technical aspects of environmental risk assessment, not on the business and financial aspects of risk management.

Industry began in the 1990's to search for better methods of environmental risk management. In 1996, a new committee, Enterprise for the Environment (E4E),

was formed by the Center for Strategic and International Studies (CSIS) in cooperation with the National Academy of Public Administration and the Keystone Center (Ruckelshaus, 1997a, 1997b). The committee was chaired by William D. Ruckelshaus, past Director of the US Environmental Protection Agency. This effort involved a knowledgeable and diverse group of individuals representing virtually every sector of society. The committee reported:

"The following 12 elements, taken together, outline E4E participants' consensus vision of an improved environmental protection system. E4E participants believe the environmental protection system should:

1. *Maintain basic standards of environmental protection, and effectively and efficiently prevent and control threats to human health and the environment.*
2. *Ensure that all environmental laws and regulations are fairly and consistently enforced.*
3. *Distribute costs and benefits fairly, accounting for impacts on both present and future generations, and address disproportionate impacts on any group in society, especially low-income individuals, people of color, or other disadvantaged groups.*

4. *Set and pursue clear environmental goals and milestones for the nation, states, localities, and tribes, and use understandable indicators to measure progress.*
5. *Adapt and adjust policies, strategies, and systems based on experience and new information.*
6. *Generate, disseminate, and rely on the best-available scientific and economic information.*
7. *Offer flexibility of means coupled with clarity of responsibility, accountability for performance, and transparency of results.*
8. *Rely on a broad set of policy tools, including: (a) economic incentives that are aligned with environmental goals, (b) reward for superior environmental performance, (c) stimulate technological innovation, incentives for changes in individual behavior, and (d) disclosure of consistent and accurate source-level performance information.*
9. *Place authority, responsibility, and accountability at the appropriate level of government.*
10. *Promote collaborative problem solving and integrated policymaking by all branches and levels of government.*
11. *Promote high levels of environmental stewardship and continuous improvement in environmental performance.*
12. *Create decision processes that meaningfully involve affected stakeholders and engage all citizens in protecting the environment."*

It was the belief of this committee that financial incentives, environmental management and company goals needed to be used in the future to provide for a sustainable environment. However, as noted in this report, little information is available on how individuals make these choices.

The American Institute of Chemical Engineers (1997) presented, "Principles for Risk-Based Decision-Making in Public Policy," with the following statements:

"Risk Management Principles:

- *Resources should be directed to the most severe risks and to those that can be reduced in a cost-effective manner, thus providing the maximum benefit to society.*
- *Each major new health, safety, and environmental regulation should be based on a scientifically and technically credible risk assessment accompanied by an analysis of the costs and benefits of the proposed regulation.*
- *Each government agency that administers programs relating to human health, safety, or the environment should undertake a comparative risk analysis of the human health, safety, and environmental risks within its jurisdiction to assess their relative severity. The comparative risk analysis*

should be used to establish regulatory and budgetary priorities to assure that the nation's resources are wisely allocated.

- *Risk reduction options should be evaluated in terms of feasibility, costs, benefits, social equity, flexibility, and competing risks, as well as the range of plausibility of estimated risks and associated uncertainties in the data and methods used to assess risk.*
- *Government agencies should provide an opportunity for public input throughout the risk management process.*

Risk Assessment Principles:

- *Government agencies should develop standard procedures, which should be uniform across the government to the extent feasible, for the conduct of risk assessments and associated peer review.*
- *In undertaking risk assessments, agencies should establish and maintain a clear distinction between: (a) the identification, quantification, and characterization of risks; and (b) the selection of methods for managing risks.*
- *Risk assessments should be based on the best available scientific methods and peer-reviewed data. They should use policy-driven default assumptions, inferences, models and safety factors only in the absence of relevant available scientific data, and the scientific and policy basis for*

their use should be explained. Risk assessments should consider and discuss both supporting and non-supporting data.

- *In conducting risk assessments, agencies should use an iterative approach and employ the level of detail and rigor appropriate and practicable for reasonable decision-making on the matter involved, taking into account the significance and complexity of the potential agency action and the need for expeditious action.*
- *Risk characterization should specify, to the extent practicable, the populations and resources at risk, the expected risk or central estimate of risk for specific populations, each appropriate upper-bound or lower-bound estimate of risk, the range of uncertainties in numerical estimates of risks, and explanations of exposure scenarios.*
- *Risk assessment, risk characterization, and associated guidance generally should be subjected to independent, external peer review by panels broadly representative of persons who have scientific and technical expertise in the subject matter. No competent reviewer should be excluded from the peer panel provided there is full disclosure of actual or potential interests.*
- *The federal government should foster advanced methodologies for assessing health, safety, and environmental risks; enhanced scientific data collection to improve the accuracy and relevancy of risk assessments; and innovative technologies to reduce risks to human health*

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and safety and the environment.

Risk Communication Principles

- *Government agencies should conduct and report the results of risk assessment in a manner that promotes rational decision-making and informs public input into the process of making agency decisions.*
- *Information published on the results of risk assessments should be comprehensive, informative, and understandable. The policy-driven default assumptions, inferences, models, and safety factors utilized in the risk assessment should be clearly identified, and the scientific and policy basis for their use should be explained.*
- *The public should be informed of the magnitude of risks and the assumption and uncertainties in assessing risks in a way that helps citizens develop proper perspectives on risks and their relative severity in relation to other risks faced in their daily lives."*

These statements amount to principles of ethics and management, and from them it appears that research is needed as to how managers in charge of environmental systems make decisions regarding risks associated with the industrial processes and business aspects. Companies require assistance in

decision processes, which could include a decision support system as a management tool.

2.2 Business and the Environment

2.2.1 Business and Environmental Risk

Information on environmental risk associated with business is limited. Mullin and Sissell (1996) quoted Ross Stevens, Dupont CEO, as stating that shareholders are not interested in pollution prevention or waste reduction—they are focused only on the immediate problem. They want companies to shift their emphasis from avoiding liability to pursuing financial opportunity through better environmental management techniques. The stockholders are interested in yield improvement, sales growth, cost management and cash and earnings generation as a result of improved environmental management strategies. One of the overriding messages in this article was that improvement in environmental management must come from a business focus rather than regulatory drivers, which in the past has been a "command and control" system of enforcement.

Paul Harris (1995) stated that Dupont has integrated environmental performance into an operating principle at every business unit. The company's commitment to safety, health and the environment (SHE) is built around its vision of sustainable

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development and their long-standing goals of zero injuries, illnesses and accidents; zero environmental and transportation incidents; and zero waste and emissions. These goals are stated in Dupont's 5-year old program in the petrochemicals business. The management scheme is for all programs and projects worldwide to meet both regulatory and voluntary goals for environmental management.

Norman Rimich (1996) provided information on a survey conducted by Arthur D. Little Inc. regarding the wall that exists between companies' environmental and business staffs. Managers at 185 corporations in the US and Canada cited two critical problems that often impede an environmental manager's ability to improve their company's environmental management:

1. A lack of integration between environmental and business issues in the company.
2. Their own failure to convince management that the environment is an important business issue.

A number of top environmental managers stated that top management does not understand or support environmental functions and their effect on the bottom line.

Frost and Wilmshurst (1996) performed a survey of the top 500 Chief Financial Officers (CFO's) of Australian companies. They suggest that company accountants are not committed to environmental accounting practices and have only a limited amount of involvement in environmental management. Shocking was the statistic that only 43% of respondents believed that environmental information was important in the company's annual report. Most CFO's (63%) were neutral on the question regarding the accountant's professional responsibility in advocating the environmental agenda.

Barbara Quinn (1996) reported on Southwire Co.'s environmental management philosophy that "environmental management is a real business issue, not fluff or feel-good." In 1990, Southwire had an environmental incident at one of the company's facilities, which branded them an "environmental criminal." This labeling proved to be a wakeup call to company officials. Southwire changed their decision making process to include environmental management pollution prevention policy, which includes several requirements, from organizing a team to design flow charts for residuals, quantifying and qualifying those residuals, establishing applicable regulations and costs and identifying alternatives. Results of the program, which was implemented in 1995, have included eliminating halogenated solvents, reducing paint use by 30% and recycling of paints and thinners. This has resulted in an overall cost reduction for the company which has added to the Stockholders' equity.

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Tom Barron (1996) reported on a Bristol-Meyers Squibb (BMS) program which analyzed the various product lines within the manufacturing facility, from beginning to end of the product production process in an individual product line. BMS found that performing an audit of the line activities and changing the process could result in a reduction of $250,000 per product line per year. This added profitability to the company was discovered through environmental and energy savings.

Parnell and Herlugson (1996) researched information on managing corporate environmental costs and liabilities. In this article about the oil and gas industry, the authors provided information on the various national and international laws that the oil and gas industry must comply with and how a company with a long-term strategy, similar to BP Exploration, could minimize risk, reduce environmental liability and increase credibility with the public sector.

The above examples provide information on why companies need to be interested in combining their business and environmental management systems. This combination can add significantly to the overall profitability of the company while providing a better living environment to the public.

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2.2.2 Environmental Risk Assessments and the Business Environment

Bayard Cantrol, et al., at Battelle (1994) Pacific Northwest Labs provided information on balancing risks, costs and benefits fairly across generations. They described the misinterpretation of discounting cash flows for future problems and generations. Future expenditures in an inflationary economy result in less cash payments based on today's dollars. Cantrol stated that companies would be predisposed to wait to process these expenditures due to the perceived lower cash payments. However, with environmental problems there is too much uncertainty regarding their true future costs, therefore, it is very difficult to determine what cash flow in today's dollars would be required for future expenditures. The authors developed a model for policy making that consisted of a fault tree. In this analysis, they determined expenditures that required the benefits and costs to be either discounted within a 30-year time period or not discounted beyond a 30-year time period. For example, capital and investments were discounted, but aesthetic or existence values were not discounted. The authors made decisions based on the potential effect of pollution or environmental policy on future generations. This type of economic analysis provides a different approach toward the overall benefit and cost analysis questions.

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Mark Shere (1995) does not agree that risk assessment for public health protection is a wise choice of evaluation tools. Mr. Shere states that risk assessment has too many uncertainties to develop any useful ranking of risks. He cites several cases where the Environmental Protection Agency (EPA) was performing risk assessments that had multiple factors of safety and uncertainties regarding to the affects of chemicals on human health. Mr. Shere provided information pointing to the idea that environmental laws do not specifically state that risk assessments are to be used for evaluation. The only exception to the use of risk assessment being required by law is the Clean Air Act amendments of 1990. However, the courts are very much in favor of utilizing risk assessment techniques of comparison due to the belief that a layperson can make intelligent choices on what risks are acceptable. However, Mr. Shere believes that determination of health risks can only be made by health professionals who understand the consequences and the interactions of various chemicals on the human body, not through a court interpretation. He does state however that EPA could utilize risk assessment in the evaluation of environmental activities.

Adam Finkel (1995), the current director of health standards for the Occupational Safety and Health Administration (OSHA), reported that risk assessments being promulgated in the new laws by the current congress are not being applied correctly. He stated that risk assessments that lower the standards for human health protection have been adopted by Congress. He believes that Congress

would like risk assessments to be based on the health effects on the average person instead of the population at risk, children and the elderly. In basing regulatory compliance on the effects to the general population, the standards utilized for environmental risk assessment can be lowered. Mr. Finkel compared studies of animals contracting cancer in a certain environment with actual human epidemiology studies. The comparisons showed that the predictions of the animal studies were very close to actual human epidemiology cases of cancer development. Mr. Finkel stated that costs were more of a variable than risks associated with human health or environmental protection. Therefore, he recommends that risk assessments be utilized as a tool as these risk assessments are still being developed and more focus needs to be placed on the economic analysis that is combined with risk assessments for actual decisions regarding public policy.

This section of the literature search provides information regarding the risk assessment and how it should be viewed with economic concerns. The authors have stated that financial and economic concerns need to be addressed but should not be the overriding factor in making decisions. This is especially true as it relates to health concerns and future generations.

2.2.3 Environmental Management and Accounting Systems

Maxwell (1998) provided a study of environmental management and accounting systems at the Honda of American plants in East Liberty and the Toyota facility in Marysville. Ohio. The environmental manager at the Honda plant utilized ISO 14000, the environmental management system set up by the International Standards Organization, as an aid to help focus on the upcoming environmental inspection from the pending visit of her boss from Tokyo. Management personnel in Japan stated that environmental management and compliance is a very important aspect of the company's core values and needed to be addressed on a plant-by-plant basis. However, there was a conflict in the core values of Honda's desire to produce the best quality cars at the lowest possible price and still be an environmental leader. Based on the pure cost accounting method, it was thought by the environmental manager that meeting both the environmental goal and company profitability was not possible. In addition, the environmental management team from Japan also compared the US Honda plant with the US Toyota operation.

As a comparison between environmental management systems, Maxwell highlighted the difference between Honda and Toyota. Honda utilized a management style that was developed and implemented on the local plant level. Toyota used a management style that was developed on the corporate level.

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This lead to several differences in implementation of "lean thinking" as it relates to an environmental management system:

- The Honda operation provided for plant specific solutions to environmental problems but suffered from not learning from other Honda facilities.
- The Toyota plant had a more coordinated effort to implement environmental compliance company wide, but the solutions did not always fit the specific situation that existed at the plant level.

There were also cultural differences between the US and Japan plants' operations. Japan has a much more flexible system on environmental regulation which allows companies to meet the regulations through innovative methods, even though their discharge standards tend to be much tighter. The US utilizes a "command and control" system of regulation, which leads to a reluctance by plant personnel to try new ideas. This reluctance is due to personal and corporate liability for mistakes. If a company or individual does not meet the standards set by the government, they can be held personally liable for the fines and penalties. In some extreme cases, an individual can be sent to jail. Therefore, environmental managers in the US do not want to utilize innovative techniques in most cases due to the legal liability. The differences in approaches between Honda and Toyota are highlighted below.

- The Honda plant personnel were educated about the goals and then were allowed to develop site-specific systems to handle these goals. They developed several systems which lowered overall costs of the operation and provided a significant reduction in waste products. The lowering of pollution and costs was achieved through pollution prevention techniques.
- Toyota's approach was from a more centralized vision, which was delegated from the corporate office in Japan. This approach resulted in reductions of overall pollution, but specific techniques were not developed for each Toyota facility. Therefore, not all environmental directives were helpful to plant personnel and some opportunities that the Honda facility realized were not possible under the corporate system developed by Toyota.

Overall, the Honda approach was more beneficial to each individual plant but required more resources and communication for implementation. In this study, each plant accounted for environmental expenditures differently. However, in both cases, the cost of environmental compliance was the focus of the study. Both companies utilized their company goals and values to set up their environmental management system. These company goals allowed the environmental management system to lower both its costs for environmental protection and the amount of pollution, which is a significant finding. Therefore,

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Maxwell found that you could achieve a higher standard of environmental protection while minimizing the cost for compliance.

Kennedy (1998) found that an environmental management system did not work well without the use of a total cost assessment tracking system. The author emphasized that decision makers typically have only limited information on which to base decisions. He concluded that the company manager not only needed better cost information but this information needed to provide both business and environmental information at the same time. Another point made by the author was that environmental regulations are in a constant state of change. These changes dramatically affect how a company forecasts the different costs associated with an environmental activity. Therefore, a tracking system is required in order to provide the decision makers with enough and better information to make rational decisions in a timely manner. This tracking system also provides a total picture of the cost for environmental compliance, which affects the strategic direction of the company. Kennedy developed a tracking system of Total Cost Assessment (TCA) and discussed how this could be utilized to assist managers in making better decisions. TCA is used in conjunction with Activity Based Costing (ABC), which is allocated to four different groups:

1. Unit level – activities performed on individual units or processes
2. Batch level – activities that process batches of units or processes

3. Product sustaining – activities that maintain the producing capacity for a product line
4. Facility sustaining – activities that maintain the functioning of the facility

These four groups of activity based costing, along with TCA, will provide the decision maker with information on the estimated costs of environmental activities, as well as the actual costs once the activity is implemented. The end result of this type of measurement will be the ability to predict the profits associated with different programs and different decisions that are implemented.

Miles (1997) takes the environmental management system and provides information on how this will affect a company's marketing plan. In this article, Miles points out that public perception of the environment has shifted from the individual to the organizational level. This shift has the implication that the whole company is responsible for the environment not just environmental managers or their department. This shift has caused the business community to find a way of implementing environmental compliance in an orderly fashion, resulting in the development of environmental management systems and programs. These systems and programs are a very important part of the marketing program of companies, giving them the ability to state that environmental compliance is important to the company and that the company can show how it is in compliance with this global program.

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This section of the literature search provided several authors' viewpoints on how environmental management systems can be combined with the business system. They point out that accounting systems need to be part of the overall management system. The authors also state that environmental management systems have to be consistent with the company's goals and values.

2.2.4 Traditional Decision Support Systems

Cothern (1994) addressed the environmental risk decision making process and pointed out that environmental decisions require values, perceptions, assessments and ethics, with ethics being the most important. The concept of ethics in environmental decision making is not new, however, it is not normally considered an active part of the process. Cothern cites that many who think that science is ethically neutral confuse the *findings* of science with the *activities* of science; data are neutral but actions may not be. The author provides the following hierarchy of ethics:

Judgments (and also policies) → Rules → Principles → Ethical Theories

Ethics can also be defined as a decision problem in the second degree, that is, a decision about how decisions are going to be made in the future and what

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principles these decisions are going to be based upon. This implies that the principles which result in specific rules will then affect values or judgments.

Cothern then provides six different models for decision making. This information was developed while at the Battelle National Laboratories. The first is the Ideal model, where all information is known, including all technical and scientific aspects; the health consequences of all possible alternative actions; the exposure routes of all possible causes; the costs now and in the future; the social, political and psychological consequences of all decisions; and all other possible relevant information. The Ideal model is not possible or practical because we do not live in this perfect world nor do we have access to all of the data necessary.

The second model is the National Academy of Sciences "Red Book" Model (National Research Council, 1982). This model is defined by the following:

(1) Hazard characterization → (2) Dose Response assessment

↓

(3) Exposure assessment → (4) Risk Characterization

Following risk characterization will be risk estimation and risk acceptance, which will hopefully lead to achievable risk. While this model provides insight into the

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technical aspects of a risk assessment, it does not involve the practical aspects of what a business could afford or how to prioritize any of the risks. This model also does not consider ethics as a specific aspect of the model.

The third model is the Cost-Benefit Analysis. While this model compares today's cost and associated benefits, it does not provide a view into the future. Again, ethics is also not addressed in this model.

The forth model is the Framework Model and includes the following aspects that need to be evaluated with regard to a particular problem or situation:

- Attitude towards technology (positive or negative)
- Uncertainty (statistical, lack of knowledge, incomplete knowledge, methods to use)
- Risk taker or risk adverse
- Causality (including confidence)
- Burden of proof, who has it and what are the criteria
- Rationality
- Voluntariness or social order

This model tries to incorporate values into the overall evaluation, recognizing that environmental risk analysis is not just an activity but a decision tool and in

addition is not neutral or value-free. However, ethics is not specifically addressed in this model.

The fifth model evaluated was the Channel Model. This model provides a column for the problem, a comparison column for the values or value-laden components and a subsequent column for a solution or decision. The values or value-laden components include "Objective, hard or Quantitative" and "Subjective, soft or Qualitative." This model provides a method to evaluate various elements which are normally missing from a risk assessment. However, the order of the elements and the feedback of decisions are missing from this analysis.

The author recommends a sixth model, the Continuous Model, as shown in Figure 2.1, be used for environmental risk decision-making. This model includes the following:

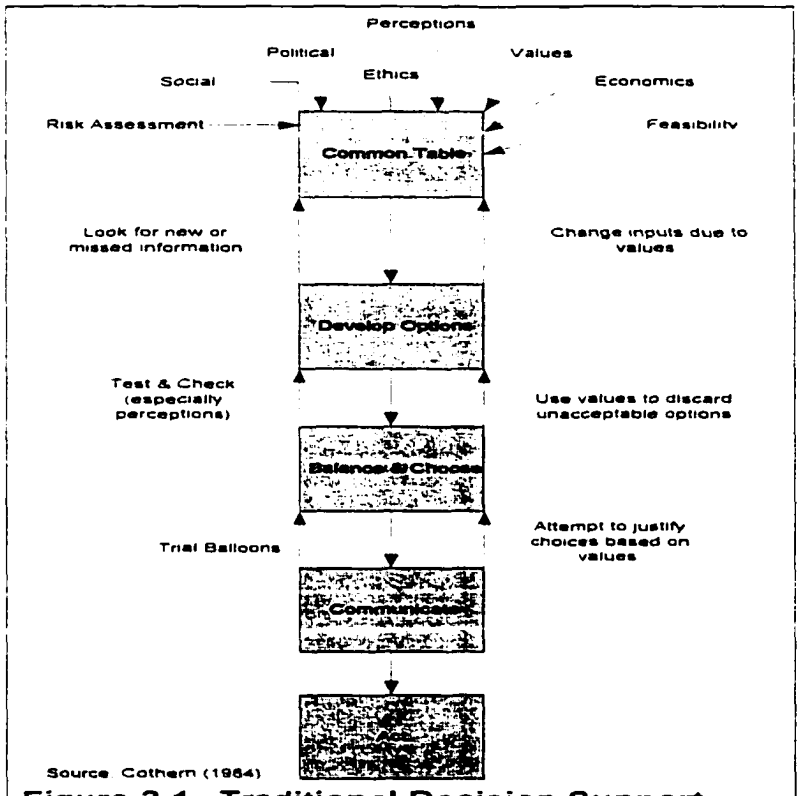

Figure 2.1 Traditional Decision Support System
This is an example of the early environmental decision support systems

As shown by the figure above, the Continuous decision model provides for a limited feedback loop. This increase in information, due to the feedback loop, provides for a more consistent and realistic environmental risk assessment. Also note that communication is one of the last tasks, representing communication with all of the stakeholders present in the model, allowing for acceptability and reaction prior to implementation. If this communication is two-way, as

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represented by the model, then the likelihood of an acceptable environmental and business solution is greatly increased. The author promotes the use of additional research in the area of environmental ethics as they relate to company management. This research will assist in simplifying the decisions required within industry regarding environmental matters. The author noted that this model will take a considerable amount of time to develop a solution within a company.

Hakkinen and Leep (1994) discuss the concept of environmental risk management as it relates to environmental risks, values and perceptions. Their concept of environmental risk management was developed at Proctor and Gamble. They based their environmental risk assessment program on four major themes:

1. A scientifically sound risk assessment
2. Public involvement in the environmental risk assessment and management process
3. Focusing resources where the greatest or maximum benefit can be achieved
4. Utilizing environmental regulations which are performance based and allowing companies to make collective risk reductions in the most cost-effective manner

A specific case was detailed where a joint study was performed between Amoco and the US EPA. In this case study, it was found that the cost of compliance for disposal of residuals utilizing the existing US EPA "command and control" system was $2,100 per ton. The alternative to command and control is a performance based system, allowing the company to be innovative in their approach to the solution of the environmental problem. The regulations specify the end result but do not dictate the solution in a performance based system. If a performance-based system was used at the Amoco facility, the end result would be lower emissions by 20 to 25 percent and a cost for disposing the waste residuals of only $500 per ton. Utilizing a performance based system results in a better outcome through lower emissions and a cost savings of over 300 percent.

Brackeen and Gibson (1995) reviewed and implemented an environmental management system utilizing cost accounting as one of the deciding factors for environmental decision making at the Rocky Flats environmental technology site. Rocky Flats is employing a Systems Engineering Analysis (SEA) at this site to help the environmental management team make decisions on how to handle the various waste streams produced at the facility. This system includes the tools of simulations of alternative processes, cost analysis and reporting, risk analysis and decision support processes. The SEA was composed of the following components:

- Logic diagrams
- Facility and land-use analysis
- Facility and site characterizations and inventory
- Static material balance
- Economic analysis
- Environmental risk analysis
- Engineering analysis simulator
- End-state analysis
- Technology needs assessment

This process requires that the desired level of cleanliness be decided prior to beginning the process of remediation. Once the desired level of cleanliness is chosen, then the system will assist the facility manager with the logical sequence for determining the final waste disposal site. This logic sequence is combined with a cost estimation system, socioeconomic models, data analysis and the site-specific database system. These databases and estimation systems work with the engineering analysis simulator that provides the different alternatives. The authors state that this SEA approach is unique to decision models and addresses the full life-cycle requirements of a complex environmental cleanup and supports decision-making relative to selecting the most cost-effective approach.

Kooros and McManis (1998) provided information on strategic investment decision-making utilizing initial inter-temporal resource allocation. This paper advanced the methodology for optimizing investment decisions through utilizing a Modified Delphi process for a consensus-orientated approach to decision making. The authors found that it was very important to provide decision makers with an adequate source of information. They suggested the following format for providing information to the decision makers:

1. Identify the corporate strategic investment performance factors
2. Determine objectively the relative importance of these factors whose sum constitutes the decision preference or the model's objective function
3. Identify conditions under which these factors are affected, with time as the common denominator
4. Structure an appropriate modeling framework capable of optimizing investment strategies, i.e., determining which investment project should be considered in a specific timeframe in order to maximize the overall financial performance.

The authors concluded that the best decision model for multi-objective criteria was a consensus-orientated data and modified hierarchical goal-programming approach; specifically, a weighted-assignment model to meet the stated

objectives. The authors were able to test and verify this model using several case studies.

Gopalakrishnan and Dugal (1998) provided information on two separate theories of decision-making: (1) strategic choice and (2) environmental determinism. This article compares these two theories on decision making and the three factors which effect these decision theories.

1. Industry related factors
2. Organization related factors
3. Time related factors

These theories were studied by reviewing the organizational issue of free-will versus determinism.

The free-will or strategic choice theory states that a manager can act relatively autonomously and be proactive with choices made within the organization. The determinist theory believes that managers are severely restricted by the organization through environmental and structural conditions that exist. The authors found through their research that industry-related factors will restrain a manager's ability to make decisions by regulations (such as environmental regulations) and the stage at which a product is within the industry life cycle. The

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organization-related factors that were examined and found to influence decisions included top management characteristics and organization size. The authors argued that each organization does not have one or the other type of decision making environment, but rather a degree of either. They also found that the time frame in which decisions are made affect which theory applies. For short term decisions, the strategic view is the preferred choice, however, for long term views, managers typically utilize the deterministic method for decision making.

Lewis and Butler (1993) provided research on group decision making in the presence of a multi-person, multi-objective framework. Due to the fact that most environmental decisions cannot be made without a myriad of conflicting objectives, the authors searched for an optimal solution that maximized as many objectives as possible. To accomplish this, they studied two techniques for decision-making: (1) Multiple Objective Linear Programming [MOLP] and (2) Simplified Interactive Linear Programming (SIMOLP).

The MOLP technique studied by this research team was an interactive approach and was found to provide the most promise to decision makers. In this approach, the decision maker is confronted with a set of objectives. Utilizing judgment, the decision makers will sequentially evaluate a limited number of solutions in order to direct movement toward a good solution. This interactive evaluation process continues until the decision maker expresses satisfaction with a solution.

Through the interactive process, the decision maker gains valuable insights into the problem and the possible efficient levels of objective achievement. The opportunities to learn about alternative solutions and to revise opinions during the optimization procedure makes interactive MOLP techniques particularly attractive for the multiple decision-making situation.

The SIMOLP procedure begins by individually minimizing each model objective function to yield a set of k efficient solutions and their criterion vectors. A compromise solution is found by solving the model with a weighted sum objective function. The decision maker will eliminate the least preferred solution until the final solution is chosen.

The authors found that MOLP was preferred by most decision makers. This was due to the interactive aspect of the decision process and the ability to better understand the other decision makers in the group. The SIMOLP was not the preferred solution mainly due to the lack of interaction, even though the preferred solution from the model was obtained with fewer iterations when compared to the MOLP model.

Nutt (1992) described the success of using formulation tactics for organization decision making. Nutt asserts that formulation tactics are a very important parameter for decision making due to the constraints that these tactics place on

the final solution or search for solutions. These constraints could be caused by prescribing boundaries or dictating the features of acceptable responses, or they could limit solution searches by broadening the scope of inquiry. Nut also stated that there were four types of formulation tactics. These tactics were:

1. A single action (the idea tactic)
2. Exploring several types of feasible responses coupled with justifications of the need to act (the reframing tactic)
3. Overcoming a list of difficulties or concerns (the problem tactic)
4. Finding the desirable outcomes (the target tactic)

Nutt's research found that reframing was the most successful tactic, but this tactic was seldom used. The reframing tactic was used by top level managers, not by the line managers. Most of the line managers utilized the problem or target tactic, which solved the immediate problem but did not solve the problem that was recurring or the problem with the process.

Margaret Curtin (1995) developed a management decision tool for environmental manufacturing. In this study, the emphasis was placed on the internal decision-making process needed to limit the production of hazardous wastes. In this decision process, the following were evaluated:

- Waste Outputs
- Initiation Decision
- Operations Decision
- Modified Product
- Selection

This decision process involved sequentially evaluating the different decisions based upon the various costs for each alternative. Then, the net present value of various alternatives, based on their life cycle cost, is determined with and without the risk. This decision process tries to bring in some of the financial aspects of the business into the decision process.

The National Center for Environmental Decision-Making Research (NCEDR) at the Oak Ridge National Laboratory has developed various strategies for decision-making models (Dale, et al., 1999). The Center recommends that any decision model include the desires of the stakeholders. They recommend that the models trend toward wise conflict management and open-minded collaborative learning. They are opposed to the processes which are exclusively centered on analysis or an elite corps of decision makers.

This section covered traditional decision support systems. All of the papers covered in this section provided methods to help with the environmental decision

process. These decision models have progressed significantly from the early 1980's, when the first models were introduced. Traditional decision support systems did not address how the engineering and business aspects could be combined. The traditional decision support systems also did not address how experts might be used in this process. The next section will discuss how experts can be used in the environmental decision support system.

2.2.5 Naturalistic Decision Support Systems

In the late 1980's and early 1990's, several authors were beginning to focus on how experts made decisions in a natural environment. This was a new development in the research into decision support systems. This new direction allowed researchers to redesign training programs to be more effective in areas where decisions were actually being made rather than in the laboratory. This relates to research by environmental engineers needing to make quick decisions in a changing contextual environment. The Naturalistic Decision Making process was specifically designed to assist individuals in this type of work environment.

Patricia Benner (1984) provided a study of nurses in practice. Ms. Benner writes of her research experiences regarding how nurses make decisions and how experience plays a role in this decision process. A nurse's experience with making decisions is similar to that of an engineer in that nurses are able to detect

certain patterns and determine a proper course of action depending on the inputs that they are gathering. This is similar to the engineer "having a feel for the numbers." Experience levels add to the overall improvement in decision making. The author finds that better decisions can be made by training nurses on how to obtain this experience level: the training needs to be completed through situational analysis.

In 1989, Zsambok (1994) provided information on a new term regarding decision-making: Naturalistic Decision Making (NDM). The definition of NDM is:

> "*The study of NDM asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast paced environments, identity and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which the operate.*"

This type of decision-making was being researched by the US Armed Forces and other organizations where decision making in a natural setting was being studied (Zsambok, 1994). NDM was originally researched and developed by Klein and others. These researchers found that decisions made in the laboratory were not following behavior in the field. Once they discovered this difference, they found that NDM was better suited for the following types of decisions:

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1. Ill-structured problems (not artificial, well-structured problems)
2. Uncertain, dynamic environments (not static, simulated problems)
3. Shifting, ill-defined or competing goals (not clear and stable goals)
4. Action/Feedback loops (not one-shot decisions)
5. Time-stressed (as opposed to ample time for tasks)
6. High stakes (not situations devoid of true consequences for the decision maker)
7. Multiple players (as opposed to individual decision making)
8. Organizational goals and norms (as opposed to decision making in a vacuum)

NDM is applicable and valuable to the environmental engineer due to the above characteristics. The environmental engineer will need expertise in order to make decisions as the context of problems is constantly changing and engineers will be required to work with numerous groups and conflicting requirements to solve each problem as it arises. Therefore, it is important to determine the most appropriate decision support system model for each particular situation.

Gary Klein (1994, 1999) has summarized his work in NDM through several research projects. These projects involved the study of diverse groups from army commanders to navy pilots to design engineers. In Klein's research, individuals were studied in natural settings to find out how they made decisions

during normal or stressful situations. In most cases, there were three different types of decision models utilized; these included:

1. Simple Match – This is a situation which is recognizable and the decision maker will utilize a solution which they have used in the past and which they know will work, based upon experiences.
2. Diagnose the Situation – This is a decision model in which the decision maker will obtain information about a situation and will recognize parts of the solution but not others. For the parts that the decision maker does not recognize, they will attempt to predict what will happen with combinations of known actions. These expectancies will help the decision maker to narrow the choices on the next course of action.
3. Mental Model – The mental model is one in which the decision maker does not recognize the problem and will utilize a "mental model" to attempt to determine the next course of action. They will try to visualize what will occur with different options. This option requires the most experience of the three models.

Klein's research shows that by knowing how experts utilize different decision models in a changing context, this knowledge will help in the training of future experts. This is directly applicable to the environmental engineer in the business setting. For example, if the business manager knows what kind of additional

expertise is going to be required to make environmental decisions regarding the management of the company, then they can teach the less experienced engineer the areas to research. In the business setting, this might include additional information on the requirements of internal rates of return or how the tax rate will effect decisions on these rates of return. The decision models allow the opportunity to understand how the expert makes a decision, which then allows for better instruction of individuals that have less experience.

Another researcher in NDM, Lipshitz (1994), stated the following:

"The normal logic that most research people develop is establishing some facts and building on those, deciding [based on those facts] which questions you really need to have answered, and going after those answers...The scientific logic says you really go for certainty. Of course, I think I have been involved in the management side long enough to know that this is an impossibility."

"I think what you find when you get out into the cold, cruel world of business is that you never have all of the information and there's always a bunch of facts that are missing... Most of the time when I get into a problem I find that I don't have the answers I need, I don't have the data I need...Let's say, the dumber you are as an engineer or technician on the technical side of the house, the better

manager you will be...[As a general manager] one and one doesn't equal two! You're not dealing with black and white. You're dealing with a gray area."

This quote summarizes the need to have expertise but not in the way most people view it. The expertise that is needed is the ability to make decisions without having all of the data needed for the perfect world decision. This requires critical thinking on the part of the environmental or business manager. The environmental engineer will be required to compile relationships between known information and then attempt to model these relationships into a solution. This will be done through a series of "quick tests" that are performed mentally and produce the "feel for the numbers" type of thinking.

The current state of research in decision support systems has moved from a static approach to decision models to a more dynamic approach. One of the first complete environmental models provided in this dissertation includes many of the considerations that need to be taken into account when making an environmental decision (Figure 2-1). These include ethics, economics and stakeholders' interests among others. However, once an alternative is chosen with this type of model, the decision support system becomes static in that the feedback loop does not allow for changes of an alternative even though the context of the problem has changed. Other authors have provided decision support systems which outline how to make decisions with regard to economic or financial

interests, but did not allow for corporate goals or company values. Then, in the late 1980's and early 1990's, several authors started research in Naturalistic Decision Making. This research determined how experts made decisions in the field and how these decisions were made in a changing context. The later developed models will be very useful in the area of environmental engineering. This is due to the expertise needed and the fact that the environmental problem is constantly changing.

2.2.6 Mini-Delphi Method for Evaluation of Risk Assessments

The Mini-Delphi technique was developed in cooperation with Dr. Evan Vlachos (1999) at Colorado State University. Dr. Vlachos provided references for "Exercises in Futurism" which detail methods of forecasting and extrapolation of survey results. This work was combined with information by Arlene Fink. (Fink, 1995a – 1995e) The Mini-Delphi technique involved asking survey questions to obtain answers based on the present as well as the future. The Delphi technique was developed to ask questions that reflect an expert's thoughts into the future. The technique includes asking a series of questions which systematically obtain expert opinion on various subjects. A normal Delphi will obtain this information through a series of questions and feedback of the answers by all of the experts. This allows the experts to see the answers to the questions from the other experts in the survey. In a Mini-Delphi survey, 6 to 20 experts are needed to

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meet the criteria prescribed by Vlachos. In the Mini-Delphi, the survey was not sent back to the experts, but clarification of the survey answers was obtained through telephone conversations with at least two-thirds of the experts. In most cases, the expert agreement was very good on the questions, and additional clarification was not required.

2.3 EPA Programs Incorporating Risk Assessment and Environmental Business Aspects

How does the US EPA, which is one of the main controlling factors in how industry responds to the environment, view environmental risk as it relates to the business aspects of a company? The Common Sense Initiative (CSI), a new program created by the US EPA, has bearing on the concept of environmental management, risk assessment and environmental economics (EPA @ commonsense, 1999). The purpose of CSI is to provide a framework where industry and the regulatory community can work together. EPA has specifically stated that they would like to work "*from conflict to consensus; from piece-meal to holistic; from inflexibility to innovation.*" This approach can only be obtained with the proper incentive offered by the EPA. The incentive that EPA has proposed is a relaxation of tight regulations regarding water, wastewater and hazardous waste requirements. This relaxation of requirements does not lower

the environmental standards, but will increase compliance and efforts in achieving these environmental standards.

For example, in the CSI Metal Finishing group, the standards for environmental compliance were increased by 90% (EPA @ strategic goals, 1999). Industry participants (over 300 participants in the charter group) agreed to reduce their hazardous waste output by over 50% and reduce their wastewater discharge standards by 90% (on a mass basis). This type of reduction is monumental for the industry, which has fought any type of changes for the last 20 years. However, to achieve this level of compliance, EPA agreed to reduce paper work violations, reduce the amount of records required for compliance and provide a more cooperative framework between industry and the EPA and state agencies. EPA is also proposing an electronic reporting system for companies that are part of the CSI. This will significantly reduce the amount of paper work for small to large companies and reduce the overall cost of environmental compliance. Mr. McCormick (1999) with EPA Region 8 stated that this program of electronic reporting is being piloted in Denver, Colorado.

The CSI is an example of utilizing business financial aspects for changes within an environmental management system. In this case, the metal finishing industry was willing to change their behavior in accordance with the financial and regulatory drivers provided by the EPA. This is a good example of what kinds of

factors are used for environmental and business risk assessment evaluations by environmental and business managers of companies. As shown by the above example, companies are willing to significantly reduce their affect on the environment when the regulatory agency is willing to lower the impact on the business aspects of the company.

Another program development by EPA is Project XL (EPA @ projectxl, 1999). This program is similar to CSI in that companies benefit from participation in the program. However, rather than just the EPA setting the goals, the companies were allowed to participate in the discussions regarding the best approach to environmental management. This project has the following guidelines regarding the implementation of these goals:

1. Produce superior environmental results beyond those that would have been achieved under current and reasonably anticipated future regulations or policies;
2. Produce benefits such as cost savings, paperwork reduction, regulatory flexibility or other types of flexibility that serve as an incentive to both project sponsors and regulators;
3. The goals of Project XL are supported by stakeholders;
4. The program will achieve innovation and pollution prevention;

5. The project will produce lessons or data that are transferable to other facilities;
6. The goals and projects are feasible;
7. The project will establish accountability through agreed upon methods of monitoring, reporting and evaluations; and
8. The goals will avoid shifting the risk burden, i.e., do not create worker safety or environmental justice problems as a result of the experiment.

Additionally, if the applicant to the program is a community, the community should develop strategies that: (1) present economic opportunity and (2) incorporate community planning. Projects are selected by EPA on an on-going basis, and they must have the full support of State, local and tribal governments.

This section of the literature search provides information on how the US EPA or the government is encouraging companies to change their behavior with respect to environmental management systems. They are accomplishing this change through financial influences. This information provides a good basis on how government might influence companies to change when provided the opportunity and what might drive this type of change in the future.

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2.4 Examples of Companies Incorporating Risk Management and Environmental Business Strategies

One of the guiding principles of incorporating environmental risk assessment with business strategies is that there is an economic or business reason for this incorporation. In most cases, this will consist of eliminating a direct cost or through a different management of environmental problems, adding to the bottom line. This addition could be in the form of reduction of wastes, purchasing less raw materials through a more efficient process or lowering energy expenses. The following are several companies that have benefited economically from this type of process.

2.4.1 The 3M Example of the 3P program

In 1975, the 3M Corporation started a program, 3P, which stands for Pollution Prevention Pays (3M @ environmental, 1999). The purpose of this program was to implement a pollution prevention program and document the savings to the company. This program was implemented company wide on an international basis. Since 1975, this program has prevented emissions of 750,000 tons of pollutants to the environment and saved the company over $790 million through 4,590 different pollution prevention initiatives. In the 1997 annual report for 3M, the following was stated:

3P was established because it is more environmentally effective, technically sound and economical than conventional pollution controls. Natural resources, energy and money are used to build conventional pollution controls, and more resources are consumed operating them. Conventional control only constrains the problem temporarily; it does not eliminate the problem, which is the objective of 3P.

3P has been recognized around the world for its achievements. This environmental/conservation initiative has been praised by environmental organizations, officials of many governments and by the United Nations. It has been copied by a number of companies. Among 3P's environmental honors are top awards from President Clinton's Council On Sustainable Development, the National Wildlife Federation's Corporate Conservation Council and the World Environment Center.

As stated above, 3M Corporation has made the decision to try and change their corporate vision toward the environment. This has been beneficial to the company through cost savings and public perception. The company has instituted this program using the following methods:

1. Product reformulation
2. Process modification
3. Equipment redesign
4. Recycling and reuse of waste materials

An example of the application of this principle can be seen by looking at an overspray procedure in a paint booth at a 3M plant. Over 500,000 pounds of waste overspray material is produced annually. This overspray paint material needed to be disposed in a hazardous waste incinerator. A new system of spraying paint on parts was developed, which cost the company $45,000 in a capital investment. The cost savings resulting from the lower use of resin and the practical elimination of the waste from this process saved the company over $150,000 per year. The environmental and economic payback was less than 4 months.

As shown by this example, companies will modify their behavior in favor of the environment if there is an economic incentive. With a payback of this magnitude and timing, most companies will accept the capital investment. The added benefit is the reduction of 500,000 pounds of pollutants that are no longer emitted to the environment.

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2.4.2 Dow Example

In 1994, the Chief Executive Officer for Dow Corporation, Mr. Frank Popoff, was interviewed regarding their internal program of full-cost accounting (Chemical Week, 1994). Mr. Popoff stated that at the Dow Corporation, all production units were charged for their waste streams directly. This was a change from past practices where environmental charges were prorated on the basis of sales or something similar, so the employees did not have any incentive to save money. When full-cost accounting was implemented, the costs for environmental aspects of the company were charged directly to the individual production units. A large incentive with the program was reducing the cost for disposal of waste materials. When the individual production units were charged for their specific waste stream, then the cash savings could be shown by lowering the amount of wastes or providing a process change which resulted in a less toxic waste stream. This resulted in a more profitable production unit, which passed on profitability to the employees.

Mr. Popoff was also asked about the Rio Earth Summit in 1992. His comments emphasized that environmental noncompliance cannot be a competitive advantage for companies in the future. He holds that economic development and environmental reform are interlinked and that there cannot be one without

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the other. This concept was also translated to environmental risk assessment with the following quote:

> *"One of the things that's coming out of Rio and Sustainable Development is the concept of risk assessment. To some elements of the environmental community it seems a Trojan horse -- a great way to damage environmental reform, by making us go through this procedure to assess risk and damn it, we don't have time to assess risk, the future of the planet is at stake. I think the public has forced the environmental community, the legislature, and the Administration to say wait a minute, zero risk -- which we used to think a possibility -- is beyond us, there are trade-offs, and risk assessment and analysis is in our best interest."*

From the above statement, it appears that corporations are encouraging the use of collective risk assessment and environmental management systems to allow for sustainable development. With a free market economy, this concept will be critical. The business sector of the economy is the only sector that has the capital to provide for cleanup and maintaining a sustainable development program. Therefore, companies will need to apply this concept to their business strategies in the future.

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The above section provides information on how companies are modifying their behavior on their own, without the influence of government. These two examples provide information on how companies have found the financial rewards to change their behavior as it relates to environmental management systems.

2.5 International Aspects of Risk Assessment and Business Strategy

Companies are continually becoming more international in their scope of services and products. This section will discuss how this might affect their behavior as it relates to environmental management systems. Holme (1995) has provided information on the international aspects of risk assessment and business strategy arising from the requirements of the European Community. This business concept is tied to the "Eco-Auditing and Management Scheme" (EMAS), a comprehensive program to improve the environmental performance of manufacturers in member countries. This program highlights the following elements:

1. Initial environmental review: Companies will assess their performance in such key areas as life cycle impacts of their products and production processes, use of materials and energy, waste management, worker safety and involvement of the public in corporate decision making.
2. Three-year audits: Every three years, independent specialists assess

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company performance and the adequacy of management systems using widely publicized yardsticks.

3. Environmental statements: Every three years, companies prepare public statements detailing the types and amounts of pollutants they have released, the types and amounts of wastes they have generated and the use of materials and energy.
4. Validation and disclosure: These reports are reviewed for accuracy by accredited environmental auditors and then released to the public and "competent authorities" for their review.

As shown by this program, risk assessment of operations in conjunction with business strategies is extremely important to companies. It will be important to understand how a company will make these decisions and what factors are considered in order to prevent an improper decision process.

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2.6 Presidential Commission on Risk Assessment and Risk Management

In 1990, the US Congress passed the Clean Air Act Amendments of 1990 stating, "to make a full investigation of the policy implications and appropriate uses of risk assessment and risk management in regulatory programs under various Federal laws to prevent cancer and other chromic human health effects which may result from exposure to hazardous substances." This statement created the Presidential Commission on Risk Assessment and Risk Management. Omnen (1997 a,b) reported on the Commission, which began meeting in May 1994 and produced a final report in January and February, 1997.

The Commission developed a risk management framework (see Figure 2-2). This framework is a departure from the one chemical-one risk scenario. The National Academy of Sciences/National Research Council, as well as other scientists and federal agencies, issued many reports with recommendations for improvements in risk assessment and risk management. The commission developed a new risk management framework, which is comprised of six stages:

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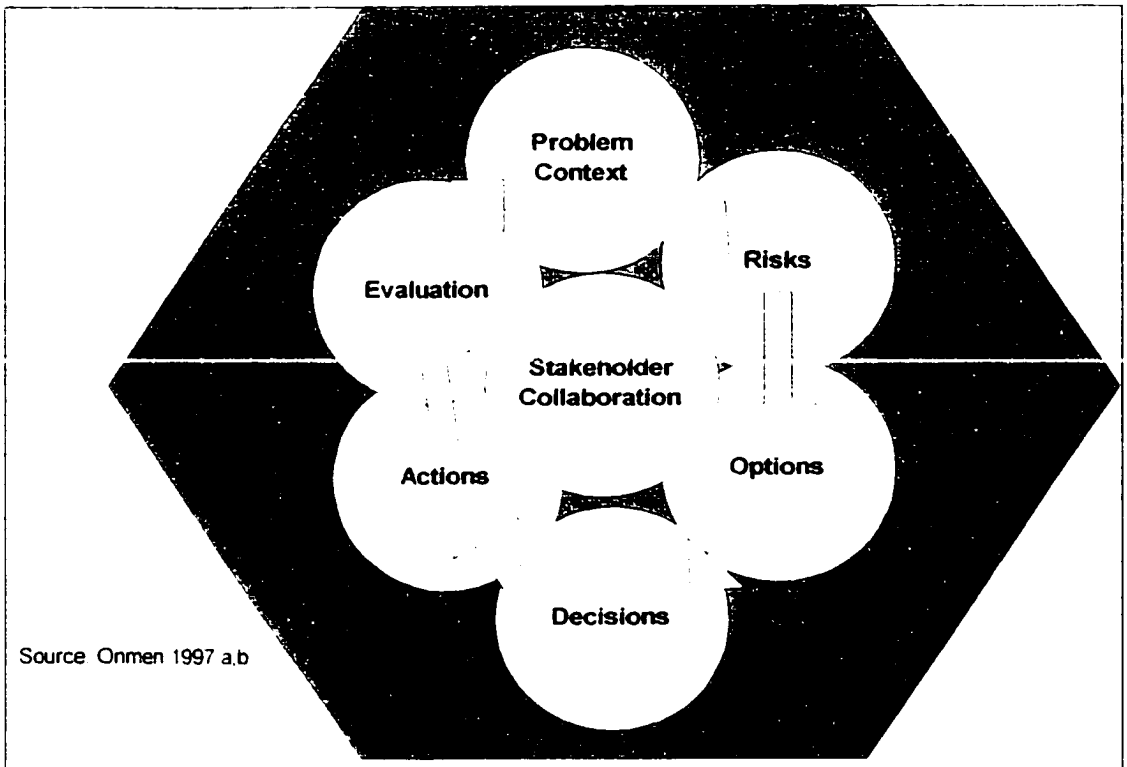

Figure 2.2 Risk Management Framework
How stakeholders will work together on decisions regarding the environment taking into account various risks

As shown by the above Figure 2-2, the following steps would be taken:

- Formulate the problem in a broad context
- Analyze the risks
- Define the options
- Make sound decisions
- Take actions to implement the decisions
- Perform an evaluation of the effectiveness of the actions taken

Note that this format explicitly embraces collaborative involvement of the stakeholders. This process can allow for refinement during the decision making process as new information is obtained.

As found in the literature search, the Commission noted that risk assessment and risk management are only tools to allow for information gathering and decision-making. It was the intent of the Commission that scientists go beyond scientific observations of the relationships between exposures to chemicals and pollutants and their associated effects on people, the environment and test systems and to rely on many scientific inferences and assumptions to answer social questions about what is unsafe. In order for this concept to be effective, the risk assessment process has to be able to communicate the process and allow for decisions to be made in a collaborative manner.

The Commission was also very explicit with regard to economic analysis. They stated that this analysis should not be the overriding factor in the decision process. One of the main reasons for this is the problems with discounting cash flows, as well as the potential to affect future generations. However, the public stated in sessions that costs need to be an important factor in this process. The Commission stated that the public understands that zero emissions are not possible, and costs need to be part of the discussion on what risks are acceptable.

The Commission also defined the difference between benefit-cost analysis (BCA) and cost effectiveness analysis (CEA). CEA begins with an assumed goal and then explores the methods that could achieve that goal to identify the least costly one. BCA has a different role in that it can be used to assess the benefits and costs of alternative health-based standards with different levels of health protection. The Commission provided the following example:

Table 2.1 – Example of Benefit-Cost Analysis (BCA)
How BCA can assist in decision making by converting health effects to incremental cost
Source: Onmen 1997 a,b

Possible Standard	No. of Annual Health Effects Averted	Incremental Benefit	Annual Cost of Controls ($ x 10^6)	Incremental Cost	Incremental Cost ($ x 10^6 per effect averted)
Status quo 100 ppm					
50 ppm	500	500	50	50	0.1
20 ppm	950	50	150	100	0.2
5 ppm	990	40	500	350	9
1 ppm	999	9	2000	1500	170

In this example, utilizing BCA could assist the EPA in selecting the standard that should be adopted by translating health effects into dollar-equivalent units with such methods as willingness-to-pay. This concept reflects the economic principle that environmental quality and risk reductions ultimately are things people value, just as they value conventional consumer goods. In this example,

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if the public were willing to make an investment of $5 million per health effect averted, then the standard would be placed between 20 ppm and 5 ppm (i.e., for 20 ppm: 950/150=6.33). This method would not be acceptable if the "willingness-to-pay" was not known.

CEA, on the other hand, can help the decision maker determine which cost is acceptable and select a standard that is consistent with that cost and in keeping with other desired goals of the decision making process.

While the BCA method is beneficial and easy to understand by the public, it is difficult to find the willingness-to-pay values. CEA, on the other hand, does not require this type of number. However, the weakness of CEA is that benefits cannot be quantified and are not included in the analysis. The main point of the Commission on BCA and CEA is that all analyses should include explicit information about the assumptions and uncertainties that underlie the estimates of costs and benefits. The other recommendation by the Commission is that additional research is needed in the decision making process and how it can be incorporated into risk analysis and risk management.

This section highlights the US Government's position on environmental risk assessment: financial and business aspects need to be part of the environmental management system, but are not the driving force in the analysis.

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2.7 Summary of the Literature Search

The literature on risk analysis since its beginnings in 1984 with the National Research Council has been relatively limited. The literature on environmental effects and how they relate to the business systems has been expanded in recent years. A review of risk assessment, business systems and associated information is helpful to understand the current needs for future study. The literature suggests that risk assessment is needed in the future for environmental policy decisions. In addition, environmental economics and business systems need to incorporate risk assessment into overall business strategy and operations. This literature search highlights (1) the increasing concern with the far reaching consequences of collective risk and (2) how the business and engineering sections of companies have collaborated together on risk in a much more complex equation that includes values and professional ethos. Along with this more complex equation; the time horizon of planning has increased to a minimum of 5 to 20 years; more professional disciplines are involved in the decision making process; and a richer menu of visions, goals and objectives is being formed by companies for the future.

Chapter Three discusses how information can be obtained from business leaders on how they make decisions involving environmental risk. I utilized a Mini-Delphi technique to gather this information from 15 experts in the environmental

management system field. By utilizing these experts, we will be able to determine how business and regulatory leaders incorporate risk into environmental management systems. In addition, we hope to find out how they will incorporate these environmental management systems into the overall business and regulatory systems, which involves risk assessment.

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CHAPTER THREE

USE OF MINI-DELPHI TECHNIQUE TO OBTAIN EXPERT OPINION

3.0 Background on the Mini-Delphi Process

The Mini-Delphi technique was created at the RAND Corporation to provide a method for the systematic aggregation of expert judgment (Dalkey, 1963). The original research was part of the US Air Force's attempt to obtain expert opinions through intensive questionnaires with controlled feedback on areas where data were lacking or too expensive to obtain. Mini-Delphi techniques are most useful where insufficient data exist to derive meaningful information on which to base scientific conclusions. In these cases, the Mini-Delphi techniques are useful to obtain informed judgment of data in place of actual experimental data.

Leung (1978) provided information on the use of Mini-Delphi procedures that have been applied to a wide range of studies, including long-range forecasts of economic and technical developments for industrial decision-making, estimation of costs for new product development, estimation of incidence of various disease states in the total population and others.

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The Mini-Delphi consists of the following phases (Linstone, et al., 1975):

1. The first phase is to characterize the subject of the study and to provide information pertinent to the issue that will be the focus of the questionnaire. It is important not to limit the discussion but to make sure that all participants are focused on the subject of concern. The experts are asked to fill out the questionnaire and respond as to their future orientation of concerns.

2. The second phase is to receive the questionnaire back from the experts and then to develop an understanding of how the group views the issue. The next part of this phase is to compile the differences for a controlled feedback to the group of experts.

3. The third phase is to have the panel of experts answer the questionnaire again with the advantage of the feedback from phase two. Again, the results are compiled and analyzed.

4. The last phase is a final evaluation of the previously gathered information for either consensus or divergence of opinion on future orientation of events.

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Lindstone (1975) stated that the common failures of a Mini-Delphi research project are imposing the project leader's views on the experts by being too restrictive on the questionnaire, utilizing poor techniques for summarizing the information from phase one of the Mini-Delphi questionnaire and ignoring or not exploring fully the disagreements that might exist in the data.

The Mini-Delphi method improves the quality of the judgments on relatively uncertain issues by experts. The basic assumption is that the most accurate assessment of a problem where data are incomplete can be obtained by canvassing a group of experts and accepting the group consensus.

3.1 Developing the Mini-Delphi Questionnaire

The Mini-Delphi used in this dissertation utilized a panel of 11 experts to arrive at a group consensus on the impact of a company's environmental management system and the effects on the overall business model.

The questionnaire was developed to find out new information about how environmental experts view and control environmental management systems in relation to the business and management aspects of the company. The questionnaire was organized into four different sections. Each section attempted to retrieve new information as well as confirm previous answers within the

questionnaire. The questionnaire, which followed the principles of a Mini-Delphi, was also developed to look into the future, as perceived by these experts.

3.2 Section I – Background Information on the Panel of Experts

Fifteen experts were invited to participate in this survey; 11 did participate. While this is a relatively small sample, the level of expertise and responsibility of the experts is high. As discussed in section 2.2.6 (page 63), the number of experts should range from 6 to 20. All of the experts in this Mini-Delphi had a college education and additional specialized training in environmental management. Two-thirds of the experts had an advanced degree of some type, either scientific, engineering or business. All of the experts were in upper management within the company and in direct charge of environmental matters. The company size ranged from a small company defined as revenues of less than two million in sales to Fortune 100 companies.

The answers to the questions in Section I provided insight as to how the experts viewed environmental management systems. In general, they agreed that the environmental arena and the business systems that are affected by it have changed substantially in the last 10 years. The experts also agreed that a change in the regulatory system, i.e., the US EPA or state/local control agencies, was going to occur from one of a "command and control" system of management

to a more cooperative approach. This is a significant area of agreement and underscores the urgency and importance of finding new business models to work within the next regulatory context.

The experts also noted that their companies had changed their values significantly over the last 10 years. This significant change in values related directly to overall business objectives and to meeting environmental criteria set by investors. The investors felt that bad environmental performance led to bad investments. Therefore, companies were being required to pay more attention to environmental matters based on outside forces that did not involve regulatory agencies. Again, this is a very significant finding because it shows that companies are being forced to take environmental measures by two forces - regulatory agencies and shareholder pressure.

Company managers also noted that with increased activity of regulatory agencies and associated fines, the engineering staff was required to pay more attention to meeting permit conditions.

Another significant finding was the shift in values of the company at the CEO level. Most of the experts felt that significant changes were occurring due to a shift of values by management teams toward a company that supports sustainable development. This shift of values toward a more sustainable

company will dramatically shift the method by which companies will make decisions in the future. This occurred because of a change in values at the CEO level. Most experts stated that this CEO shift in values was due to a generational change at this level of the company. This is another significant finding, which indicates the need for a new management paradigm.

The companies also believe that more effective auditing and measurement systems are needed for environmental management. They felt that auditing and measurement systems needed research to develop systems that would work within the engineering and business aspects of the company. Management and the business side of the company need a better understanding of the constraints and opportunities that the environmental management system provides.

There is not much information about financial matters, and most companies do not perform eco-accounting practices. Also, companies do not account for all costs associated with environmental management. Most experts feel that future measurements of financial and baseline operating activities are an important area for research and development.

The experts also noted the difference in engineering and business staff, and felt that communication was difficult due to the specialized language of the environmental engineer and the world of regulations. Several experts stated that

an effort by the engineering group was needed to convert their problems into the language of business to allow for better communication of each group's concerns in a more logical manner.

Most experts stated that they did not have a solution for obtaining potential cost savings relating to environmental management. However, they believe that the engineering staff should become more acquainted with eco-accounting. The concept of eco-accounting is the total cost analysis and the activity-based accounting that was discussed in the literature search. This will provide a better accounting of the activities that are involved in the overall company environmental effort. In addition, the financial and marketing staff should interact more with the environmental engineering staff to understand their constraints due to regulations. Almost all experts stated that they measured costs associated with the environment as a function of sales. This helped them to understand how they would compare with other companies of the same size and magnitude.

Future cost estimations of environmental expenditures are based on established targets or on past expenditures. All of the experts stated that they go through this process at least once per year. Some experts had started to separate operational costs from costs associated with environmental liability.

The companies which are known leaders of environmental management have plans for communicating with stakeholders and the public. These outreach programs varied considerably by the expert, as noted in Appendix A. Some of the experts publish an Annual Environmental Report, while others utilize their web page to provide information on the status of their environmental program. Some of the experts polled did not have a method for communicating with the public at all. They would answer questions based only on inquires or as required by environmental regulations, such as the Emergency Planning and Community Right-to-Know Act (Code of Federal Regulations, 1999).

Another question dealt with pollution prevention programs. The experts stated that they all had pollution prevention programs. Some of these were a result of the Montreal Agreement, which is an internationally based commitment to reduce greenhouse gases (EPA @ Montreal, 1998). Typically, these experts will measure their pollution prevention efforts based on the number of units produced during a year. This allows them to compare their efforts with previous years, even though the company is growing.

The last area of the survey dealt with the international aspects of environmental management. Several companies were international in scope and were already dealing with the European Union Eco-Accounting and Management Scheme. Out of the four companies that deal directly with Europe, three are becoming ISO

14001 registered. ISO 14001 registration is the environmental management certification program by the International Standards Organization. This certification states that the company has been audited by an outside agency approved by ISO and that the outside agency certified that the company has complied with all of the requirements under the certification program. The result of these activities under ISO 14001 is a higher awareness of the environmental management system on a company wide basis. These experts also stated that designs for production were changing to accept units back after their useful life. This life cycle recycling program is significantly changing the production system of complacency.

This section of the survey can be summarized by the fact that all experts stated that the changes they have experienced in the last 10 years are significant. These changes seem certain to continue and intensify, based on the answers of the experts and other observations.

3.3 Section II – Future Trends in Business and Engineering Management

In Section II, the experts were asked what they thought would happen in the future in business and engineering management systems. Most experts had a high degree of agreement.

The first question dealt with change or shift of global environmentalism. All experts agreed that a large change in global environmentalism is expected in the future. Along with this shift, the experts believed that the public will be more involved than in the past with company environmental matters. They do not feel that the public sector will be more moderate in the future and they did not feel that the public would be more understanding or forgiving when a company is working on environmental matters. This presents a near-term dilemma in that environmental experts expect a shift toward a more cooperative approach to regulation, but they do not believe that public officials will be more moderate. The shift referenced above will move to a more moderate position by 2011 to 2015, based on the opinions of the experts.

When considering three main business components—(1) company profits, (2) consumer want satisfaction, or (3) public interest—the experts stated that consumer want satisfaction is probably the most important business aspect. This would be a significant change from past company philosophy which focused on profits. The experts did focus on company profits second to consumer want satisfaction. This shift is probably due to a different and long-term focus on company sustainability. Consumers are demanding certain behavior from the company, and in order to survive, the company needs to shift its focus from profits alone to consumer want satisfaction. Companies also find that this new focus actually increases profitability in some cases.

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The experts stated that Non-Governmental Organizations (NGO's) will have some to little effect on company performance. However, they also felt that there would be some interaction with NGO's in the future. This is an important shift in how a company operates from the past. As indicated in Hoffman's (1997) work, the public, through NGO's, is affecting how industry reacts to their surroundings. NGO's, such as the Environmental Defense Fund or the Sierra Club, are beginning to cooperate with industry in an attempt to learn from each other and improve the environment.

In all cases, the experts stated that management would participate more in environmental matters within the company. They believe that public interests or third parties will also participate in the environmental management system in the future.

3.4 Section III – Future Trends for Company Environmental Management Systems

This section will discuss how the experts are anticipating changes within their environmental management system (EMS). There was good agreement among the experts that EMS will be a very important factor in business decisions in the next 20 years. The experts had good agreement that this would occur within the next 5 years.

The experts also stated that the current system utilized by the EPA of "command and control" would be replaced by a more cooperative approach of enforcement within the next 10 years. This would include a relaxation of enforcement activities for companies that are providing good environmental stewardship. Along with the relaxation of regulatory agencies, there will be a shift of more public pressure for companies within the next 10 years to achieve a higher environmental performance standard. This might be assisted through tax incentives or other governmental changes. Most of the experts did state that they were uncertain about the amount of changes in regulatory requirements in the future.

These experts also stated that with the trend for more and rapid information within the EMS, there will be a need for engineers to become more knowledgeable about company business aspects. This will occur over the next 15 years. This new technique of environmental management will include a more shared decision making process. This shared decision making process is due to the shift of management style from a hierarchical, or a vertical, organization to a more hetrarchical or horizontal organization. An example would be the marketing department being involved with "green labeling" of the company's products. Additionally, there will be the implementation of a "reasonable profit" which will incorporate the concept of environmental stewardship.

There was strong agreement that companies will incorporate the concept of risk and reward in making decisions regarding environmental management. This risk and reward concept will occur within the next 10 years. This style of management will include more involvement of the strategic management groups and the environmental management system. The growth for involvement is due to company employees demanding more integrity and sensitivity toward sustainable development. Most experts thought that this involvement by employees would occur within the next 5 years.

Communication with the public through an annual environmental report will occur within the next 10 years for most companies.

3.5 Section IV – Additional Comments by the Experts That Were Not Part of the Survey

At the end of the questionnaire, the experts wrote about topics not covered in the survey or about something they felt should be part of the survey.

Some comments focused on the consumer side of the equation. Some stated that this paradigm shift would occur more rapidly if the consumer were willing to make changes in their lifestyle. Also, the consumer needs to accept responsibility to pay for changes that will be required by the company. For the

company that understands this paradigm shift, there will be a competitive advantage in the future.

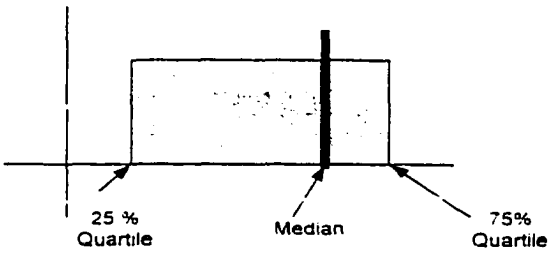
Another aspect that needs attention is risk/benefit comparisons. At the present time, there is not a good method to evaluate the true problems within the context of the business environment.

The experts then added the need to create an environmental measurement system and the need to include the EMS into the overall business management system, both in strategic and tactical management systems.

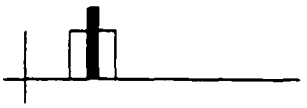
3.6 Survey Summary

Eleven experts were surveyed on the future of environmental management systems. All of the individual results are provided in Appendix A. Most of the results were also provided graphically. The graph is explained below:

Explanation of graphs:



The overall summary of the Mini-Delphi survey is as follows:

- Areas of Good Agreement: 
  - Global shift toward increasing environmentalism
  - The public will NOT be more moderate in the future with regard to environmental regulations
  - Management will be more participatory, both internally and externally to the company, in the future with regard to environmental matters
  - EMS will be very important in the future
  - There will be less EPA oversight for good performance
  - More public pressure will be applied in the future
  - There will be less uncertainty regarding environmental management in the future

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Areas of Moderate Agreement:

- There is a split between management believing that company profits or consumer want satisfaction is more important
- NGO's will have some effect on industry in the future
- EPA will move from a command and control to a more cooperative method of enforcement
- Engineering judgment will be required in the future; strong agreement to agreement
- Shared decision making between management and engineering will be a future trend with regard to the environment; strong agreement to agreement
- The concept of "reasonable profit" is held by most of the experts
- There is strong agreement to agreement on the concept of incorporating risk and reward into the environmental decision process
- There is strong agreement to agreement on the concept of strategic management groups making environmental management decisions
- There is agreement to uncertainty about company members demanding more environmental integrity and more environmental sensitivity

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- Government will begin to utilize tax incentives for sustainable development concepts

- Areas of little agreement:

  - The experts have little agreement that there is some potential for NGO partnerships with industry
  - There is little agreement with EMS being very important in the *last* 10 years
  - There is little agreement regarding the past being a predictor of more regulatory changes in the future

The following is a summary of the expert statements from the Mini-Delphi survey. These statements highlight the experts' observations and recommendations on the past and the future.

1. **Change in the environment:** There have been in the past and will continue to be in the future significant changes with regard to environmental management systems.
2. **Environmental Awareness and Competitive Advantage:** Companies today understand the need to be aware of environmental concerns. Some of the experts anticipate that there will be a competitive advantage with regard to environmental management.

3. **Need for a new Environmental Management System:** There is a need for a new system of environmental management systems. These systems need to incorporate the business and environmental engineering aspects of the company.
4. **Environmental Leadership:** The leaders of companies need to provide the necessary leadership with regard to the environment. The experts believe that this is occurring as a new generation is beginning to take leadership positions within companies.
5. **Regulatory Cooperation:** Most of the experts agree that regulatory agencies will change within the next 10 years from a "command and control" environmental regulatory management system to one of more cooperation.
6. **Public Interaction with the Company:** The public will be a driving force in the future with regard to environmental management systems. Environmental engineers will need to understand how to incorporate the public as well as the business aspects into the overall strategic and tactical planning of the company.
7. **International Business Aspects:** Companies need to start understanding that their market will be international in scale. This international market will require companies to understand and implement sustainable development techniques of manufacturing.

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CHAPTER FOUR

CASE STUDIES OF CHANGES IN ENVIRONMENTAL MANAGEMENT

4.0 Introduction

Chapter Two describes how companies are investigating new methods for complying with environmental regulations. Several companies have indicated a desire to move toward a sustainable development core value. White (1999) listed several elements of corporate behavior that lead to sustainable development:

- A company pursuing sustainable practices must be phasing out use of substances "that are systemically at odds with a sustainable world" while measuring "what share of the world's limited regenerative capacity is occupied by [its] use of renewable substances." These systemic linkages will cause companies to become more forward-looking toward the future. These linkages will also lead to the company expanding their horizons.

- Corporate sustainability means establishing boundary conditions, limits, metabolic ratios and footprints. This would be both economic as well as environmental boundary conditions.

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- Sustainability is largely defined in terms of ecoefficiency, i.e., as producing goods and services of greater and greater value relative to the burden they impose on the environment.

For purposes of this dissertation, a sustainable development core value has three dimensions of corporate behavior – namely, the environmental, social and economic aspects of the company's operations.

In this chapter, the experiences of two companies that have changed their process of environmental decisions are reviewed. These are not presented as exhaustive case studies meant to prove a research hypothesis, but to provide examples of companies shifting from only responding to "command and control" to a more cooperative mode of operation with EPA and other regulatory agencies. The case examples are limited to companies that changed after they experienced significant regulatory sanctions, but they illustrate how shifts in environmental management systems can and do occur.

4.1 Louisiana-Pacific – Montrose Facility

On May 27, 1998, the Louisiana-Pacific (LP) Corporation (1998, 1999) announced that the corporation had reached an agreement with the United States Attorney's office regarding environmental permit violations for air

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discharges. The company agreed to pay a $37 million fine over a five year period. This was the largest fine in the history of EPA Region 8 and the State of Colorado. The fine was a result of activities related to LP's Montrose wafer board plant. This summary is based on personal discussions with Mr. Gary Fields (1999), LP Montrose's environmental manager.

In 1994, the EPA stated that the LP plant had air emissions violations and plant personnel had made false statements to the EPA. In a statement to the press regarding this issue, LP Chairman and CEO Mark A. Suwyn stated

> "Getting these issues behind us has been a top priority for our management team since we came on board two years ago. LP's new management team has worked tirelessly to restructure the company and put the people and processes in place to enable us to produce the highest quality products in a highly responsible manner."

The actions that LP took from the discovery of the first infractions to the final settlement included the following:

- Installation of millions of dollars of state-of-the-art pollution control equipment
- Extensive training of all employees

- Expansion of environmental and product quality audits
- Dismissal of the CEO, president and the board of directors due to non-compliance with environmental activities

Due to the above activities, Mr. Suwyn stated, "In the last two years, the Montrose plant has gone from EPA's concern list to becoming an environmental leader." Mr. Fields reiterated this statement for local plant personnel. At this time, the company is reacting differently to all environmental requirements. The company is not only complying with the regulations, but has as a goal to be an industry leader. This goal is being met through training of all plant personnel and through installation of new equipment.

As an additional part of the plea agreement with the US Attorney and the EPA, LP will contribute $500,000 to Colorado-based programs that address air pollution reduction or remediation. Mr. Fields has stated that working with Non-Governmental Agencies (NGO's) has opened up new possibilities regarding environmental leadership. He felt that the company now understands more about what the public perceives as a good environmental corporate citizen.

An interview with Ms. Liz Smith (LP, 1999), Director of Environmental Affairs for LP, provided additional insight. When asked about the changes at LP after the fines and negotiations with the EPA, Ms. Smith stated that LP had a stronger

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resolve to be an environmental leader. She stated that environmental leadership comes from the top of the organization and starts with Mr. Suwyn. He continues to challenge the staff with ambitious and far-reaching goals. He also has instituted professional management and quality programs that provide a clearer path to achieving the leadership goals.

As part of this program to improve the environment, the company has started a program of "Business Process Improvement." "Its focus is not just on the quality of the final product, but on how we can improve the way we do business across every aspect of our company. Making those improvements contributes to safe operation of our plants, reduces costs and enhances our environmental record."

One of the challenges of the CEO is to achieve and operate with zero environmental violations and to strive for making LP's plants eliminate all waste discharges into the water, air or land. This would be an example of a BHAG that was described in Chapter Two. A BHAG is something that the company has as a goal, but knows that it is not achievable in the short or long term. Mr. Fields confirmed that LP plant personnel believe this goal is achievable but difficult due to the sheer volume of the waste and the complexity of permit provisions and regulatory jurisdictions. However, with proper training and the correct type of decision-making models and systems in place, LP believes that this goal is something to try for, even though it probably will not be realized.

An example of this type of program for zero discharge is in place at LP's Dawson Creek, British Columbia, oriented strand board plant. (LP, 1999) This plant produces over 100 tons a day of excess bark per year. Plant personnel developed a cooperative program with local government groups to compost the bark for use as an agricultural soil amendment. Another LP plant site is in New Waverly, Texas. This plant site packages the bark and other by-products for use in gardens. The bonus from these and other projects is that the waste becomes a profit center for the facility. LP recycled more than 1 billion pounds of waste in the first quarter of 1996. Much of the waste recycled was wood by-products and scrap metal that was sold to other manufacturers, generating a significant revenue stream.

In other aspects of this environmental change, LP installed 17 thermal oxidation systems at their various plants, gaining them significant knowledge in the design and operations of these types of systems. Thermal oxidation systems significantly reduce volatile organic compounds from the air stream. LP is cooperating with the EPA to help the agency understand the constraints and advantages of these systems. It is believed that EPA will not only share this information with other companies, but also utilize it to establish informed industry standards in the future.

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The above example provides confirmation of the following:

- Environmental violations can contribute to a change in policy and management systems. In this case, the board of directors, CEO and president of the company were changed completely by the stockholders due to the size and consequences of the environmental violations. The company and its board of directors, CEO and president could have been fined and imprisoned for violations of their environmental permits.
- When faced with this type of change, upper management's concurrence is required to implement change within the organization.
- The management system needs to be implemented corporate wide, not just by the environmental department. The corporate wide program was a change from the previous system and was required in order to meet the goals of the CEO.
- The company vision includes BHAG's (Big Hairy Audacious Goals) such as zero discharge from each manufacturing facility.
- Business systems found an advantage to finding new ways of handling environmental problems. These included finding a means of converting waste products into by-products of the process that became a source of revenue for the company.

4.2 AAA Plating, Inc. – Denver, Colorado

In May 1995, AAA Plating was subjected to an EPA – FBI raid for suspected environmental infractions. Fines were assessed based on the exceedence of their wastewater discharge permit. The case was recently settled. During the settlement period, the company underwent a complete transformation into an environmental leader for mid-size metal finishing firms. This information is based on personal communications with Mr. John Babish (1999), Vice President of Operations.

In 1996, AAA Plating started their own investigation into the problems associated with their wastewater discharge. During this investigation, they found that the existing wastewater treatment system had several problems with meeting the 40 CFR 413 and 40 CFR 433 regulations for electroplating and metal finishing. Part of the problem stemmed from the management environment of the regulatory agencies.

The wastewater discharge permitting process for the facility was controlled by the local Publicly Owned Treatment Works (POTW). Their regulations regarding wastewater discharge were confusing and, due to the age of the facility, some of the process discharge was under one set of regulations and requirements while another process discharge was under a different set of regulations. This

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situation was made even more complex when combined with the problems associated with attempting to conserve on water usage and limit the amount of wastewater going through the facility.

After the EPA investigation, AAA Plating decided to become a leader for environmental matters in the metal finishing industry. The management team decided to move forward with an aggressive plan to improve their wastewater discharges, produce a less toxic wastewater sludge and improve quality throughout the facility. As part of this decision process, it was decided to set a goal of eliminating all wastewater violations. This decision took them through the following steps:

- Installation of a new and innovative wastewater treatment process which utilized ceramic microfiltration wastewater treatment. This proved to be a good decision as the system was capable of removing all metal finishing metals and producing an effluent that met all of the existing requirements.
- Setting a goal to meet the EPA proposed new requirements for the metal finishing industry. These requirements are the Metal Products and Machinery (MP&M) regulations, which lower the present day standards by a factor of 10 and require the wastewater to be monitored on a mass based limit rather than a concentration based limit. These standards will affect over 10,000 metal finishing operations within the United States.

AAA Plating set as a goal to meet this standard three years before it was to be implemented; they have reached this goal.

- AAA Plating was provided an award for water reuse innovation by the Denver Water Department (1999). Due to their implementation of the new management system, they were able to save over 7.7 million gallons of water in one year, which was achieved through their wastewater reuse program. For this water savings, the Denver Water Department provided AAA Plating a check for $20,000 in the form of a one-time rebate. The water savings were obtained even with an increase in the growth of the company. "Our goal is to identify and demonstrate applications that can provide significant, cost-effective water savings that are reliable and permanent," said Elizabeth Gardener, Denver Water's manager of conservation. "If companies can be persuaded to implement water conservation techniques, we can extend our water supplies and delay the need for large dams and storage projects." The water reuse program provides an example of the company decision model and its potential far-reaching effects on other parts of the overall system.
- AAA Plating has also been a member of the EPA Strategic Goals Project (SGP), which is part of the Common Sense Initiative (EPA @ stratigicgoals). This program began in 1993 under the leadership of the EPA Administrator, Ms. Carol Browner. The program introduction states: "This strategic goals program is to provide a fundamentally different

approach to environmental and public health protection that involves all stakeholders in finding a more flexible, cost-effective and environmentally protective solutions tailored to specific industry needs." AAA Plating was an initial member of this group and has been involved in helping to set the baseline data set that will be used in the future for setting the goals of the industry.

- As part of the SGP, AAA Plating investigated methods to produce a less toxic wastewater sludge. During this investigation, they found a method of wastewater treatment that produces a non-hazardous wastewater sludge. This sludge was de-listed from the hazardous waste listing originally obtained by the company.
- The company initiated an ongoing and extensive training program to train all employees on some level regarding environmental aspects of the company.
- The major added benefit of all the work performed in the environmental area is a reduction in the cost of wastewater treatment, sludge disposal and water usage. This work has lowered their environmental costs from 13% of sales down to 8% of sales (Babish, 1999).
- AAA Plating has found an additional benefit with the institution of these environmental measures. The regulatory agencies that AAA Plating deals with on a daily basis have been more cooperative. The sharing of information also provides for a more even competition with other industry

members. Through the SGP, other industrial members are learning to reduce their impact on the environment and save costs at the same time. This benefits both the industrial members as well as the environment.

Through their activities and the choices the company made to become a leader in environmental issues as they relate to metal finishing, AAA Plating has reduced their impact on the environment through the reduction of wastewater discharges, the reduction of sludge produced at the facility, the reduction of toxicity of the sludge and the reduction of water utilized at the facility. They have also found financial benefits by becoming an environmental leader in the metal finishing field.

The above information provides confirmation of the following:

- Environmental violations can contribute to a change in policy and management systems. In this case, significant fines were brought against the company and the potential of imprisonment of one of the corporate officers is still pending.
- When faced with this type of change, upper management's concurrence is required to implement change within the organization. In this case, the company officers dramatically changed their method of doing business.

However, as a result of this activity, they found economic benefits from their actions as they relate to the environment.

- The environmental management system needs to be continuously reviewed and updated. This is encouraged by the Strategic Goals Program and AAA's internal program. This also allows for the opportunity to implement new strategies and to find new opportunities, such as the water reuse program and the sludge delisting program.
- Business systems found an advantage to finding new ways of handling environmental problems. These included finding a means of converting hazardous waste products into non-hazardous waste products.

4.3 Conclusions of the Case Studies

The conclusions of these case studies are:

1. In both case studies, the companies were forced to make significant changes in their behavior due to violations of their environmental permits, which resulted in fines and some jail time. However, both companies have stated that the changes they have made have been very beneficial and they would recommend this type of behavioral change to all other companies.

2. The cases showed that, when all technical and business aspects of the company are involved, business opportunities are identified that can provide additional profits or reduction of expenses to the company.

3. The cases showed that sharing information with regulatory agencies could provide for a shift from the command and control system of regulations to one of a more cooperative nature. Both regulatory agencies and industries can benefit from this situation.

4. The cases showed that companies need to determine their goals and visions prior to making decisions regarding environmental matters. Company management needs to be a leader in this effort and incorporate this vision throughout the company.

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CHAPTER FIVE

ENVIRONMENTAL DECISION MAKING – A NEW APPROACH

5.0 Introduction

As outlined earlier, a new approach to environmental decision-making must be utilized by companies in the future to help develop a more sustainable society. Companies are discovering the competitive advantages of manufacturing products in a more environmentally conscious manner through pollution prevention, recycling and reusing raw materials. Environmental decision-making is also assisting management in strategic decision making, including areas such as marketing and life cycle cost analysis. This requires that environmental engineers be involved in management. In the future, engineering educators and students will need to learn about the most important areas of management to be able to help companies orientate towards the concept of sustainable development.

This chapter describes a new Decision Support System that will help management understand environmental constraints and how experts can help develop a sustainable development agenda that supports the business aspects of corporate management. The decision support system will provide a more comprehensive view of the overall business setting which is consistent with

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"systems thinking" and "organizational learning" techniques for improving productivity. This "system thinking" was pioneered by W. Edwards Deming (Walton, 1986). This is an important concept for this decision support system. In the past, companies have viewed themselves as entities in complete control of their destiny. However, with "systems thinking" the entire system of the business, including outside forces, needs to be taken into consideration. The decision support system will help engineers understand how "system thinking" will affect their company and will help them to better function on business and management teams to assist in achieving the company's vision.

5.1 Necessary Conditions for Environmental Decision Making

5.1.1 Changing Context of Environmental Problems

Companies find themselves today in a shifting business environment that features changing regulations, variable and changing values of company stakeholders and changing demands by consumers. Social investors, such as those that follow the guidelines developed by the Coalition for Environmentally Responsible Economics (CERES), expect different behavior from the manufacturing and service sectors than in the past (White, 1997). This changing context requires a new decision support system, including the addition of more expertise in the environmental decision making process.

5.1.2 Requirement for expertise in decision making

Chapters Two and Four discussed how companies are cautious about making environmental decisions because of the legal and regulatory implications of poor decisions. For example, Dale (1999) showed how the cost for an environmental mistake can be 10 to 100 times the cost of an original project and how regulatory fines can be levied for bad decisions. Also, environmental decisions in the United States carry joint and severable liability through the Code of Federal Regulations (1999b), which states that a company can be liable for 100% of the cleanup cost, regardless of its contribution to the problem. For these reasons, companies have retained environmental experts to assist in making decisions, but these experts may not understand the business requirements (Hoffman, 1997).

Managers are beginning to understand that environmental experts have knowledge that can assist company profitability, such as in pollution prevention, which can reduce overall expenditures for wastewater treatment. An example of this environmental expertise was provided in Chapter Four, the AAA Plating case study. In several other studies, engineers have met more stringent standards while reducing overall costs (Curtin, 1995).

Companies have also begun to utilize environmental successes in marketing. White (1999) described companies that understand the business advantages of being "green" and he, as well as Broad (1999), provided examples of manufacturers that require suppliers to subscribe to sustainable development. An example would be the three major auto manufacturers in the United States. Companies that supply products to these manufacturers are required to demonstrate how their products are non-toxic to the environment and how they can be used or reused when the useful life of the product is over. This in turn is made known to the public through marketing techniques, letting the public know that these manufacturers are "green" and making them more appealing in the consumer's mind.

5.1.3 When an expert is required

The general manager will need to know when environmental experts are required and how they should be included in overall management. The literature survey and the Mini-Delphi survey indicated that environmental expertise has been utilized more often in the last 10 years and is anticipated to be used more in the next 20 years. In the companies surveyed, environmental expertise is becoming a larger strategic management requirement.

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Porter (1995) provided information on the exponential growth of regulations and explained the need to understand that pollution is an inefficient process, i.e., if the process were 100% efficient, there would not be any pollution. This ties directly to the need for a company to retain an expert in this area. An expert is required when a company needs to make decisions on compliance, and, in the future, to go beyond compliance. For example, under the ISO 14001 certification process, green labeling of products is permitted. Sayre (1996) found companies that deal in international markets are interested in this labeling and certification, which requires the company to move past compliance issues. This product labeling process promotes the "greenness" of the company. ISO guidelines (1996) require the company to comply with the guidelines, which include as a minimum compliance with all environmental regulations. However, these guidelines also encourage companies to move past just compliance with regulations to a higher standard of environmental practice, such as supporting sustainable development. The certification process will also have definite process modification requirements. Therefore, an expert is required due to the increase in the growth of regulations, but also to change the company to move beyond compliance.

The environmental engineering expert will be required to ensure that:

1. The company complies with applicable regulations.

2. The change in the industrial process does not create a new problem with a different media. For example, the removal of volatile organic compounds from a groundwater stream through air stripping moves contamination from groundwater to air. This does not solve the problem but moves the contamination from one medium to another, with the potential of having less regulatory control.
3. Compliance with the ISO standard can be met with the existing system. If this cannot be met, then cost implications of meeting the standard must be determined, as well as opportunities for the company to save costs through pollution prevention.

5.1.4 Do companies allow their experts to make decisions?

The literature search and the Mini-Delphi survey information confirmed that leading companies allow environmental experts to participate in the decision process. Hoffman (1997) showed that the general manager is looking for this type of guidance and wants to make sure that financial and business aspects of the company are considered. Most environmental experts do not have this type of knowledge and must learn to be able to communicate with these sections of the company.

- Leading companies incorporate the environmental decision making process into their strategic management system (Porter, 1995). However, most environmental experts will need additional expertise in the future to learn how to communicate with both engineering and business strategic planning groups; in financial planning and financial analysis and how they are modeled in the future; and the decision making process to learn how decisions are made and how training engineers can assist in the decision process.

Do experts interact with other company departments in this decision process? The answer, as noted in the Mini-Delphi, is yes. Porter (1995) and Hoffman (1997) have noted in many of the companies that there has been a remarkable shift from treating only end-of-pipe problems to becoming part of the overall strategic planning process for the company.

From the above, it is natural to ask what traditional decision support systems are and how dynamic decision support systems can improve decisions.

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5.2 *Traditional Decision Support Systems*

5.2.1 What are the traditional environmental decision support systems?

There are, of course, a number of ways to describe traditional decision support systems. Generally, they feature a decision process which is aided by information provided by experts or one part of an organization or another. This can be represented in the form of a linear planning process for an environmental engineer, as shown by Figure 5.1.

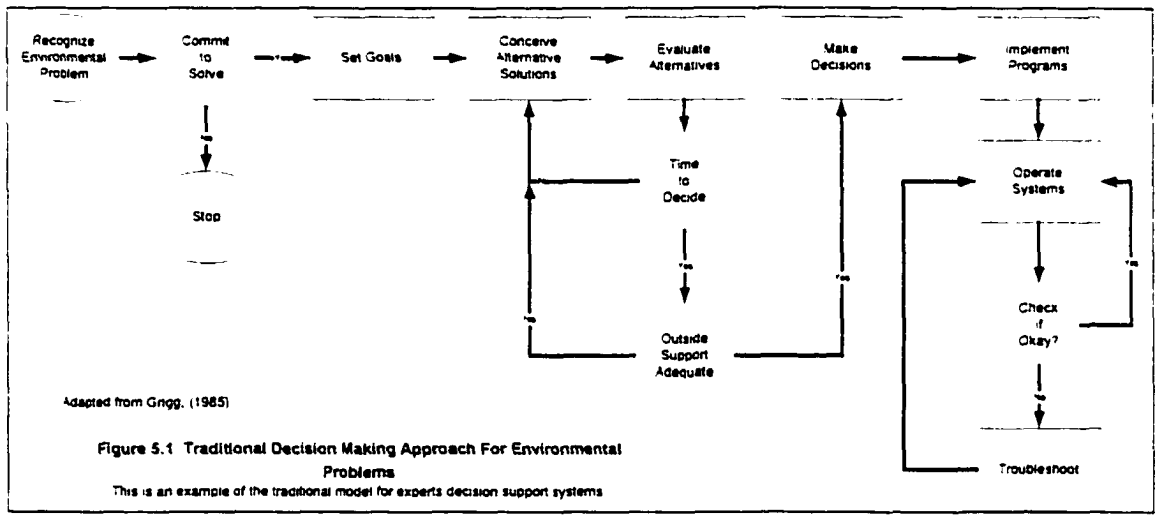

Figure 5.1 Traditional Decision Making Approach For Environmental Problems
This is an example of the traditional model for experts decision support systems

This traditional linear decision process is defined by the following:

- The environmental problem is first detected in the process, typically by the company environmental engineer. The environmental engineer then

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recommends solutions and the company decides to solve or ignore the problem.

- If the company decides to solve the problem, then the goals or criteria for success are determined.
- Once the goals and success criteria are established, a set of alternatives is developed. The alternatives will proceed through several iterations of evaluation until a best solution is found.
- The solution is implemented through operating the system. Any changes to the solution will be handled within the troubleshooting feedback loop at the end of the model.

The traditional decision support system lacks the feedback loop from the implemented solution to the goals and criteria and this lack of the feedback loop prevents changing the solution with time or adapting to new conditions. In essence, this makes the decision support system a static system, that is, the decisions cannot deviate from those based on the original goals. With the changing context of environmental decision-making, this is not an acceptable model. Problems and solutions are constantly changing and changes within the environmental field over the last 20 years have required decision support systems to change with time (Porter, 1995).

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5.2.2 Addition of feedback to traditional process

In the early 1990's, Cothern (1994), while at Battelle National Laboratories, developed a system to provide feedback to the decision support system (see Figure 2.1, in Chapter Two). This decision support system includes outside factors. For example, at the top of Figure 2.1, forces outside of the company affect decisions and provide information regarding the environment. The model includes risk assessment, social and political forces, economics and values of the company. This decision support system utilizes a common table or matrix, which includes all of the internal and external aspects.

From a business standpoint, economics differs from finance and marketing in that economics is broader and does not relate directly to the bottom line of the company in the ways that finance and marketing do. However, finance and marketing were not included in the common table or matrix. The other problem with this decision support system is the step of developing options. The external and internal aspects are constantly changing and potentially affecting the final decision. However, once the option is formulated, the decision support system becomes static again, with no feedback loop to the beginning or other adjustment factors.

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5.2.3 Problems with the Traditional Approach

The Mini-Delphi and literature search indicated that engineers are expected to become part of the overall strategic management system. In addition, by default, they have become part of the tactical decision making process. What does this mean to the environmental engineer? First, the environmental engineer will need to help determine factors that affect the operation of the company. An example would be how life cycle requirements under the European Union's Eco-Accounting Scheme will affect the future design of products. Holme (1995) has shown how this requires a company to recycle equipment from the consumer without adding an additional charge for this service. The engineer will need to incorporate this future requirement into the overall design of the system. Perkins (1999) stated that Hewlett Packard has already incorporated this requirement for recycling into their computer designs, which originate in Germany.

In addition to being involved in strategic and tactical management issues, the environmental engineer is faced with the need to make faster decisions. This results from the increase in the amount of information and speed of access to information. With this increase in speed comes the expectation from the management system that decisions need to be provided at a faster rate. So, the environmental engineer must learn more management skills and how to make more rapid and timely decisions.

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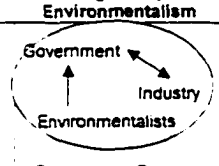
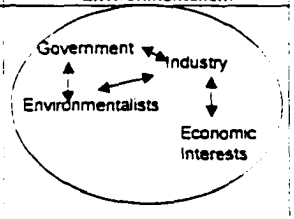
It is important to understand the history of corporate environmentalism to understand how environmental engineers made decisions in the past and how they need to make decisions in the future. Hoffman (1997) provided a short history of environmental compliance to understand the environmental engineer's change in thought process and he described how corporate environmentalism changed the culture of companies from the 1960's to the present. This information is provided graphically in Figure 5.2.

	1960-1970 Industrial Environmentalism	1970-1982 Regulatory Environmentalism	1982-1988 Environmentalism as Social Responsibility	1988-1993 Strategic Environmentalism
Organizational Field	 *Industry-Focused:* Industry is alone in the Organizational Field	 *Government Focused:* The government dominates the organizational field. Industry influence declines	 *Socially Focused:* Environmentalists pressure industry directly. Industry influence begins to rise	 *Strategically Focused:* Economic interests enter the field; Industry influence continues to rise
Dominant Institutions	*Industry is the Solution:* Self-reliance and technical optimism	*Government is the Solution:* Confrontation	*Industry and Government are the solution:* Cooperation	*The Organizational Field is the Solution:* Institutional-reliance and technical optimism
Organizational Structure and Culture	*Problem Solving:* Considered an ancillary aspect of conducting business; it is handled primarily as an operating line function	*Technical Compliance:* Although elevated to a separate corporate department, it remains an ancillary role with low organizational power; focused strictly on legal requirements	*Managerial Compliance:* Moving beyond mere technical responses, managerial structures are developed to achieve compliance based on internal constraints; Environmental responsibilities begin to diffuse throughout the organization	*Proactive Management:* Organizational boundaries blur; allowing direct influence by external interests; the environmental department reaches new levels of organizational power; Environmental considerations begin to be pushed across functional lines and back down into the line operations; integrating them into both process and product decisions

Source: Hoffman, 1997

Figure 5.2 Structural History of Corporate Environmental Compliance
How corporations have modified their behavior towards the environment from 1960 to 1993

Note the changes that have occurred over the last 40 years:

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- 1960 to 1970: During this era, industry was not affected much by government or public actions related to the environment.
- 1970 to 1982: During this era, US EPA started operating and government regulations had a direct effect on industry. The public and Non-Governmental Organizations (NGO's) also found that they could influence industry through the government.
- 1982 to 1988: During this period, the public started to influence industries directly by purchasing stock and attending stockholders meetings. Industry also started to affect the government by influencing regulations. Previously, industry would argue or sue the government believing that environmental regulations were not constitutional.
- 1988 to 1994: In this era, industry started to act more cooperatively with NGO's and the public. Industry also found that economics started to play a large role in decisions relating to the environment and the company. This trend continues today.
- 1994 to 2000: Hoffman has recently published additional information regarding corporations' reaction toward the environment. In this work, Hoffman identified the need to move from environmental management to environmental strategy. Hoffman defines environmental management as meeting regulatory compliance. Environmental strategy is where economic growth and environmental protection are brought together. The shift from environmental management to environmental strategy moves

the issue of the environment from outside the company to inside the company. This is where the company must find ways to link environmental protection and economic competitiveness (Hoffman, 2000)>

Hoffman showed how over the past 40 years companies have changed from fighting environmental regulations to embracing them. The biggest change occurred when business aspects of the company were directly affected by the environment. This change in the decision making process has a direct effect on the proposed dynamic decision support system in the next section.

5.2.4 List of Components Required for Environmental Decision Making in the Business Environment

Given that the context in which an environmental engineer makes a decision is constantly changing, both in complexity and in speed, the decision making process must be understood by the environmental engineer. Basic elements of the business decision-making process are:

1. **Company Goals:** The environmental engineer must assist the company in determining its environmental goals. Environmental goals fit into the context of traits of successful companies, such as those outlined by Collins (1995):

a. Core Values: The company needs to have core values that will be relatively stable with time.
b. Core Purpose: The company has to have a reason to exist. This core purpose is not a goal or strategy but a guiding star for the organization.
c. BHAG's: The company needs to have Big Hairy Audacious Goals. This is the method by which companies in the future will grow and expand.
d. Company Vision: The company needs to have a vision of where it will be in the next 10 to 50 years. This vision will help the company meet the BHAG's as well as fulfill the overall company values and purpose.

In identifying what it values, the company should decide how it will act with regard to environmental issues, independent of profitability.

2. **Communication Pathways:** The second element of the decision support system is communication, where the environmental engineer must communicate with overall company management. The environmental engineer is part of the knowledge base of the company and needs to incorporate this knowledge into the strategic and tactical management of the company. This communication pathway within the company needs to

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be identified by management to assist both the engineering and business units within the company.

3. **Interaction with the Business/Engineering Units:** The third component of the decision support system is the interaction of the engineering and business units. The environmental engineer in the past was responsible for the design of facilities to comply with environmental regulations. In addition, the environmental engineer will now be required to assist business units in developing new strategies for the greening of the company. Hoffman (1997) stated that this will be required in part due to the investor strategy of green groups. These groups will require companies to develop a corporate culture which promotes environmental responsibility or they will invest only in companies which follow this type of corporate strategy.

4. **Structure of Decision Making Process:** The decision process itself also needs to be reviewed. Environmental decision-making requires expertise in environmental regulations and business aspects. The decision making process needs to be performed quickly. For this to occur in a logical manner, the decision process should be outlined clearly to assist the engineer in knowing how decisions are made in a new business setting.

New components of decision making have advantages and disadvantages which require responses.

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The advantages of this new strategy for decision-making would be:

- The environmental engineer will begin to understand the overall business picture. In the past, with the focus on "end-of-pipe" treatment to meet requirements of government regulations, there was not a desire to understand the entire picture, but to solve a particular problem with meeting a regulation. Utilizing this strategy will prove to be useful because the engineer will understand financial and marketing constraints. The environmental engineer can then provide information on process changes or design changes, which will allow the financial and marketing aspects of the business to have more impact in the engineering area.
- Considering the financial aspects of the business can provide more impacts on the overall operation of the company. The financial aspects will provide for operating cash within the company. This function is critical to the success of any company. In the past, the financial aspects have been reactive to what has happened as it relates to the environment. Typically, the financial staff is involved with environmental engineering only after a disaster or release to the environment. This does not allow the financial aspect of the company to plan for expenditures. This interaction needs to occur between the engineer and the financial aspects in a more concise and logical manner to plan for environmental expenditure. When this occurs, then interaction with stockholders can be

improved because the surprise of environmental expenditures will be limited.

- Environmental aspects of the business can be integrated with marketing, the best area for staying in touch with the customer. Currently, the engineer and marketing department rarely discuss their areas of expertise. This decision strategy will lead the environmental engineer to a better understanding of customer expectations and how his or her design changes will affect them.

The disadvantages of this type of decision process are:

- This type of interaction will require both the engineer and business divisions to learn each others' "language." As noted in the Mini-Delphi, interaction between the engineering division and the business division does not occur at this time. This interaction will be difficult due to the unique language of engineering. Engineers typically communicate in a very technical language. The business sections of the company are not familiar with engineering terms and do not understand many of the topics that engineers will discuss. However, the engineer is familiar with numbers and visualization, which is the language of business. Therefore, engineers will need to attempt to understand the language of business and attempt to communicate in terms that are easily understood.

- Another disadvantage is the time required to develop a working model. Significant interaction between the engineering and business aspects of a company will be required at the strategic planning level if a company wants to move toward supporting a sustainable development concept. In the past, the environmental aspects were not included in strategic planning. However, as shown by the survey, the leaders in environmental management are already attempting to achieve this type of interaction.

Comparing advantages and disadvantages suggests that more companies will attempt to become environmental leaders. The old static style of decision support systems does not allow for the changing context in which decisions are being made. A new dynamic style is needed to adapt to changing requirements. The next section will describe this dynamic process.

5.3 Dynamic Decision Support Systems

5.3.1 Unique Features of Dynamic Decision Making Process

The dynamic decision making process differs from the traditional approach in several ways:

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1. It will be more comprehensive and involve the management team understanding environmental policy prior to making business decisions.
2. Engineering, finance and marketing will interact more and provide the collective knowledge base for the company.
3. The decision process will become dynamic in its ability to react to changing conditions in the environmental and business model. It will include more feedback and interaction and provide a more realistic view of the environmental situation and problem.
4. Solutions will be attempted at an earlier stage, helping experts make decisions quickly rather than decisions being delayed until a study is completed. With the dynamic decision making process, the decision will move at a quicker rate.
5. The dynamic decision process will help educate engineers about how decisions are made and facilitate training in this area.

To illustrate the concept of feedback, the dynamic decision model and feedback loop are presented in Figure 5.3, which serves as a preview and condensed version of the final model presented at the end of the chapter. The feedback loop will provide information back to the evaluation and analysis of the situation after the implementation of an environmental decision. This feedback loop will allow the decision maker the opportunity to change the solution with time and to continuously improve on the chosen solution.

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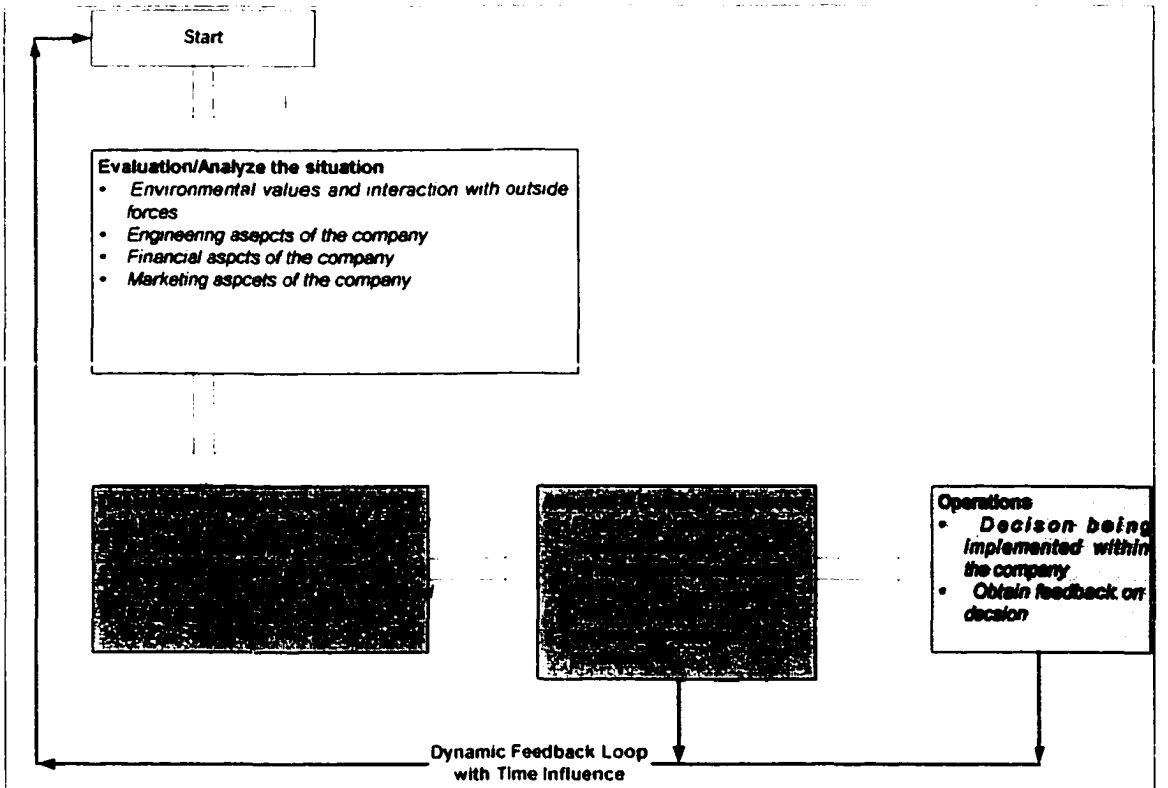

Figure 5.3 Overview of Stewart Environmental Management (SEM) Model
Overview of how the different aspects of the environmental management decision support system will interact and how these management decisions will provide new information with the dynamic feedback loop

This "Stewart Environmental Management (SEM) Model" starts with determining the company values, as defined by Collins earlier, and how the company will relate to the environment. The engineering, financial and marketing sections will interact to define the environmental problem, to understand important business aspects and to determine how to solve the problem. The model then moves to the decision stage, which is described later in this chapter. Once a decision is made, a portfolio of solutions will be created and implemented within the company. As these solutions are implemented, new information will be generated and provided as feedback to the beginning of the process.

An analog of this decision support system is the water cycle. The water cycle or hydrologic cycle is defined as the process where water on the earth changes from precipitation as rain or runoff from stormwater to subsurface or groundwater, to water vapor through evaporation and transpiration, back to the starting point of condensation and precipitation. The point of this analog is that there is not really a beginning or end to the water cycle; inputs are changing all the time. The same is true for the business and environmental aspects of companies. More companies are beginning to understand the interaction involved in the organic model for business and are utilizing this type of decision process. This organic model will implement decisions and then constantly review the outputs resulting from these decisions (Dale, 1999).

5.3.2 Naturalistic Model by Klein

At this point, a special approach to dynamic decision support will be illustrated, the Naturalistic Model of decision-making. Different decision making approaches can be taken, but Klein (1999), who focused on "naturalistic" decisions, offers a model with possibilities for implementation for environmental problems.

Orasanu (1993) explained that naturalistic decision-making applies to situations with realistic tasks and where experienced people are working under typical conditions. The conditions typically involve: (1) time pressure, (2) high stakes,

(3) experienced decision makers, (4) inadequate information (information that is missing, ambiguous or erroneous), (5) ill-defined goals, (6) poorly defined procedures, (7) higher-level goals, (8) stress, (9) dynamic or changing conditions and (10) team coordination. Note that these real-world conditions represent situations which educators might include in the education process of engineers in the future.

In particular, Klein's work documents the role of experts in decision-making and how their expertise must be utilized in a more logical fashion. In the next section, Klein's work is adapted for a dynamic business and environmental decision-making process.

5.3.3 Overview of the Dynamic Decision Support System

To assist the company with making better decisions, the dynamic decision support system must adapt to environmental problems in a world that is changing. To adapt to this changing context:

1. The company should utilize an environmental management matrix to focus their core values. This will help in determining the best approach for solving problems, focus on important business and environmental aspects and provide guidance in making decisions.

2. The second step will be the identification of the real problem utilizing the collective knowledge base of the company, including engineering, finance and marketing elements.
3. After the problem is identified and the collective knowledge base has provided input, a situational model based on the naturalistic decision making process will be utilized. This will consist of one of three decision models: (1) simple match, (2) calculating match and (3) dynamic synthesis model.
4. The model will help management reach a decision. Once the decision is made, a feedback loop will involve the environmental management matrix and collective knowledge base again to set up a loop, which will provide a continuously improving environmental management system.

5.3.4 Using the Environmental Management Matrix for Planning

The environmental matrix connects the values of the company from inception to implementation. It connects the company goals, which include core values, and the decision support system to be able to implement these goals and decisions daily.

The environmental matrix in Table 5.1, developed for this research, serves as a beginning point for the company's strategic planning committee. The top

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horizontal scale indicates the company's attitude about the environment, ranging from "Non-Compliance" to being an "Environmental Leader." The vertical scale includes business variables, such as environmental posture, business attitude or regulatory compliance. The environmental matrix guides the company on how to act and behave with regard to the environment. As an example, it will show how funding environmental projects might relate to other capital expenditures.

As another example, ethics covers decisions which can affect future generations. Groundwater contamination could release a carcinogen, which can affect the reproductive system. This type of potential contamination affects the company's responsibilities and how the public or regulatory agencies should be notified. Environmental engineers, with their specialized knowledge, should guide the company on correct and ethical decisions with regard to environmental exposures. Complete books are written on the subject of environmental ethics. This dissertation does not cover this aspect of business, but ethics are a very important part of any environmental program.

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Table 5.1 Environmental Management Matrix

Relative level of environmental compliance to management and organizational factors

Environmental Management System vs. Organizational Factors	Non-Compliance	Periodic Compliance	Basic Compliance	Aggressive Compliance	Industry Leader
Environmental Posture	Companies in this category lack an environmental posture	Full compliance is expensive, therefore this company will only do the minimum	The company can only do what is necessary to meet the letter of the law, lawyers determine action of the company	The company needs to stay ahead of the regulations; anticipation will help the company differentiate from competitors	The company is constantly finding new ways to improve the environmental management system; the environment is part of the strategic planning process
Regulatory Attitude	This type of company believes that regulations are unconstitutional and can't be followed	The company can't possibly deal with all of these issues, confusion and ignorance about different regulations	The company will only meet the letter of the law, don't work with agencies, answer only what is asked	The company needs to work with the regulators to find better ways of compliance; teaming with regulators to address issues of common interest	The company needs to strive to set the standards for the industry; companies are working with non-governmental groups and the community to improve the environment
Business Opportunity	The companies in this category do not see compliance as a business opportunity	The EMS is only for large companies due to the expenses; do not believe small companies can comply	We don't have the right resources to take advantage of the potential business opportunities; the environment is only a cost center.	The company is always looking for ways to reduce the overall costs of compliance	The company has minimized the costs for environmental compliance and is looking for new ways to handle environmental matters; business and financial aspects are very important
Required Resources	No dedicated budget or staff	Small staff with limited education & resources; spend only the minimum on training	Technical and capable staff but no integration with other company functions; the environmental section is not associated with strategic or tactical planning	Operations and management involved in developing plans for company, mostly on the tactical level – not senior management	All groups are involved in the planning and implementation of various plans
Environmental Ethics	Ethics would not enter into the decision making process	Ethics would only enter into the decision process if it was to the advantage of the company	Ethics are part of the overall decision process	Ethics become a guiding light regarding how a company will act. Future generations are part of the overall consideration	The company is willing to sacrifice profit and do the "right thing" as it relates to the environment, based on the company's ethics

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5.3.5 Involving Engineers in Company Decisions

Realistically, engineers must be involved in company decisions for this new, dynamic approach to work. Leading companies that have a goal of environmental compliance and sustainable development utilize the environmental engineer in the strategic and tactical planning functions. This is required due to pressure by the company stakeholders to stay in compliance and provide products that are friendly to the environment. To accomplish these goals, the engineer must have more responsibility with the business side of the company. Conversely, the business side must inform the engineer about consumer requirements and constraints on the product. These communications will be required on a continual basis.

To focus first on engineering aspects of decision support, refer to Figure 5.4. Engineering elements of decisions fall into four main categories:

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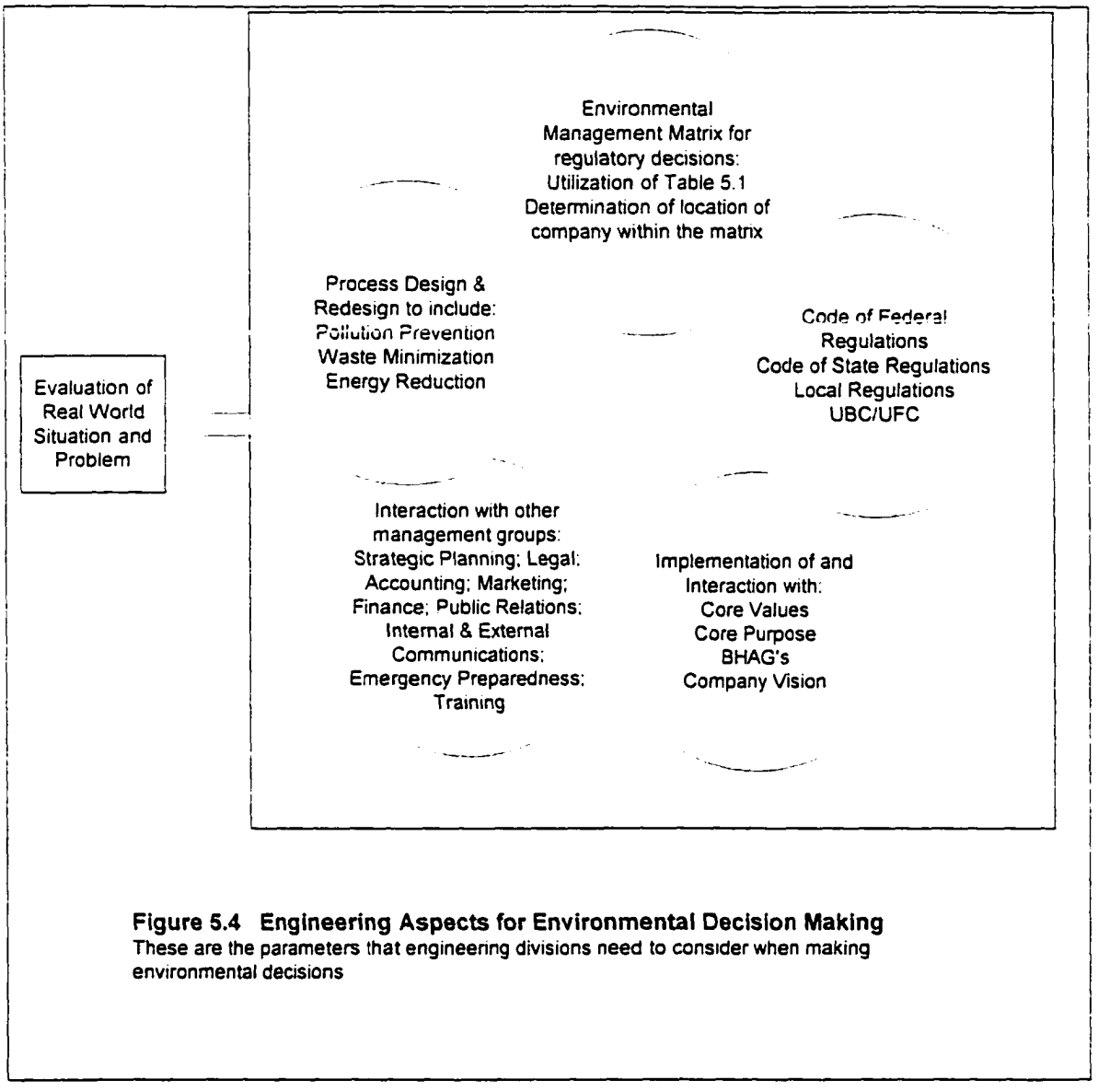

Figure 5.4 Engineering Aspects for Environmental Decision Making
These are the parameters that engineering divisions need to consider when making environmental decisions

- Strategy: Helping the company position itself on the environmental matrix.
- Compliance: Ensuring the company is in compliance with environmental regulations.
- Product development: Responding to consumer and investor demands for sustainability in design and manufacturing of products.

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- Operations: Using tools such as pollution prevention, waste minimization and energy reduction to maximize business aspects and enhance marketing to consumers and investors.

Note that these address company values, purpose, BHAG's and vision, and engineers should work with the business side of the company to realize these goals. The Mini-Delphi indicated that management is just beginning to bring engineers into the strategic management of the organization, but as companies seek leadership in sustainable development, engineers must play more important roles due to their specialized knowledge. The Mini-Delphi noted the beginning of this trend, and Hoffman's (1997) work confirmed it for strategic management.

5.3.6 Business Finance Aspects of Dynamic Decision Support System

On the other side of the ledger, the business finance aspects of the new model are shown on Figure 5.5, including involvement of the engineer.

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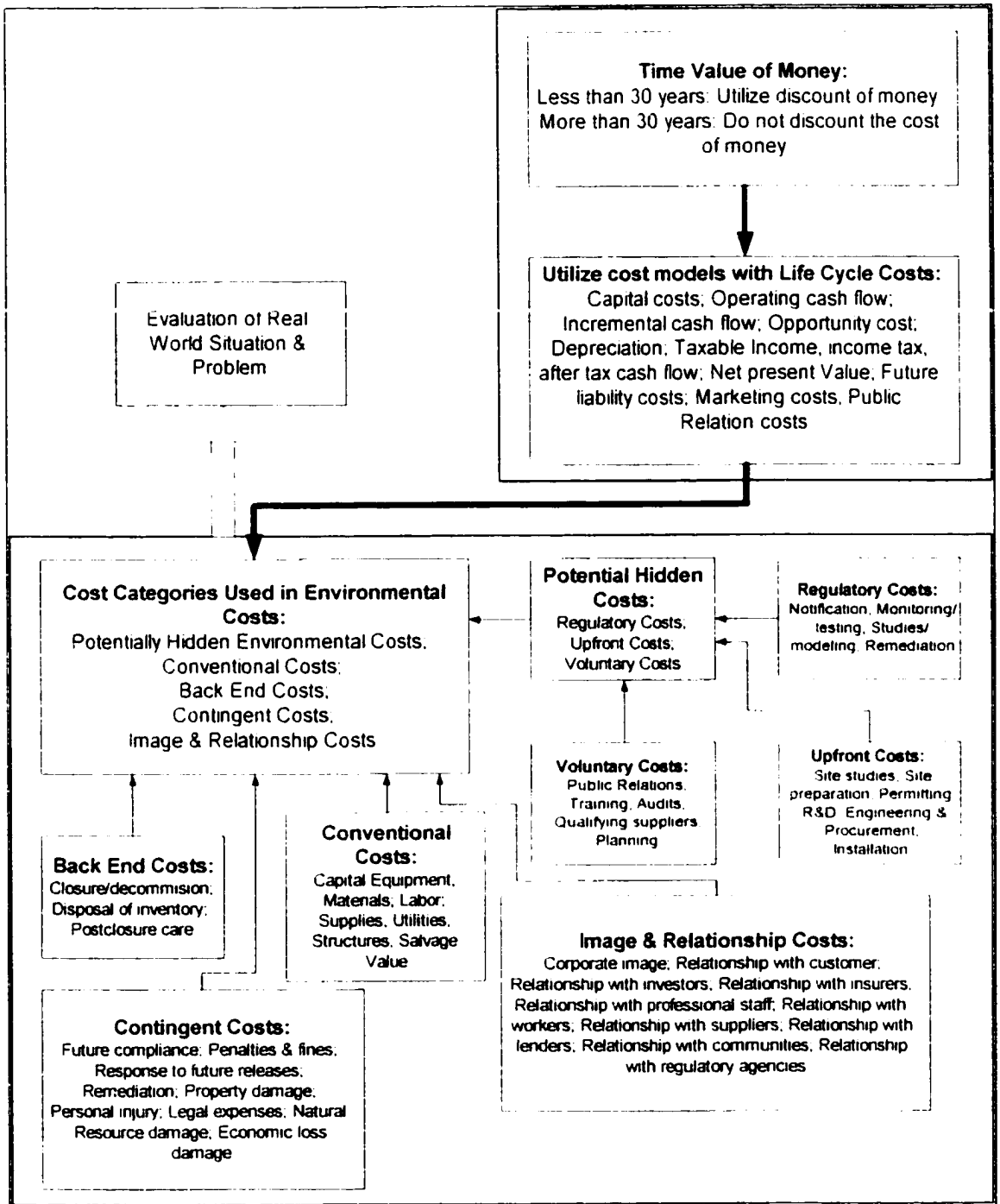

Source: Modified from EPA (1993)

Figure 5.5 Business Finance Aspects
These are the parameters that the financial management section of the company should consider when making environmental decisions

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The environmental engineer will review conventional costs associated with an environmental problem, and, as shown on Figure 5.5, many other financial aspects:

- Time Value of Money: Due to the long-term implications of environmental problems, the time value of money is very important and the engineer and financial manager must determine how long the environmental problem will persist. If less than 30 years, the cost of money can be discounted utilizing normal accounting procedures. However, if longer, there is greater uncertainty, and normal discounting practice cannot be followed due to the multi-generational aspect of the problem and predicting the cost of money that far into the future.
- Life Cycle Cost: Life cycle cost, the cost for a product from inception to eventual disposal, is a major cornerstone of sustainable development. Utilizing life cycle costs allows the engineer to design a product for reuse. An example is the European Union Eco-Auditing procedure. Hewlett Packard in Germany has instituted a manufacturing design for computers sold in Europe. These can be brought back (within 5 years) and new components can be installed in the chassis. This will reduce overall life cycle costs and produce a sustainable product.
- Potential Hidden Costs: The environmental engineer is aware of potential hidden costs, which include regulatory costs, upfront costs and voluntary

costs. Managers may not account for these costs and financial analysts normally do not anticipate them. The environmental engineer should alert the company to make sure that the costs are considered in the project.

- Back End Costs: Back end costs consist of post closure care, decommissioning and disposal of materials. Costs of post closure care are extremely uncertain and can double the cost of an entire project.
- Contingent Costs: Contingent costs can result in a project being either profitable or non-profitable and are the most difficult to predict.
- Image and Relationship Costs: The image of the company can effect its position within the market place. There is also a cost associated with this image as well as the relationship the company has with the consumer. The environmental engineer normally has little knowledge about image and relationship costs, but these can make big impacts on business outcomes. The environmental engineer can influence them by changing processes to protect the environment and then communicate this to the marketing and financial elements of the business, who can alert the public and consumers.

The above costs are not usually considered by engineers and illustrate the need for a connection between engineering and business aspects of environmental decisions. Typically, engineers only view engineering costs, plus some costs associated with pre-site acquisition or post closure care. The survey data

emphasized the need for the environmental engineer to become more familiar with other costs, consider them, then help the company understand engineering constraints and needs.

5.3.7 Business Marketing Aspects

Marketing is where the company interfaces with investors and consumers. While the company's product will only be purchased if it meets consumer demands, it is also important to consider the company image and relationships with the consumer to determine what will be acceptable to the consumer from an environmental standpoint. Industry leaders are attempting to manufacture products that have little impact on the environment. This can only happen if marketing provides engineers with insight about public expectations. The engineer can then help to design a product that consumers will accept and expect. A graphical representation of this aspect is provided in Figure 5.7.

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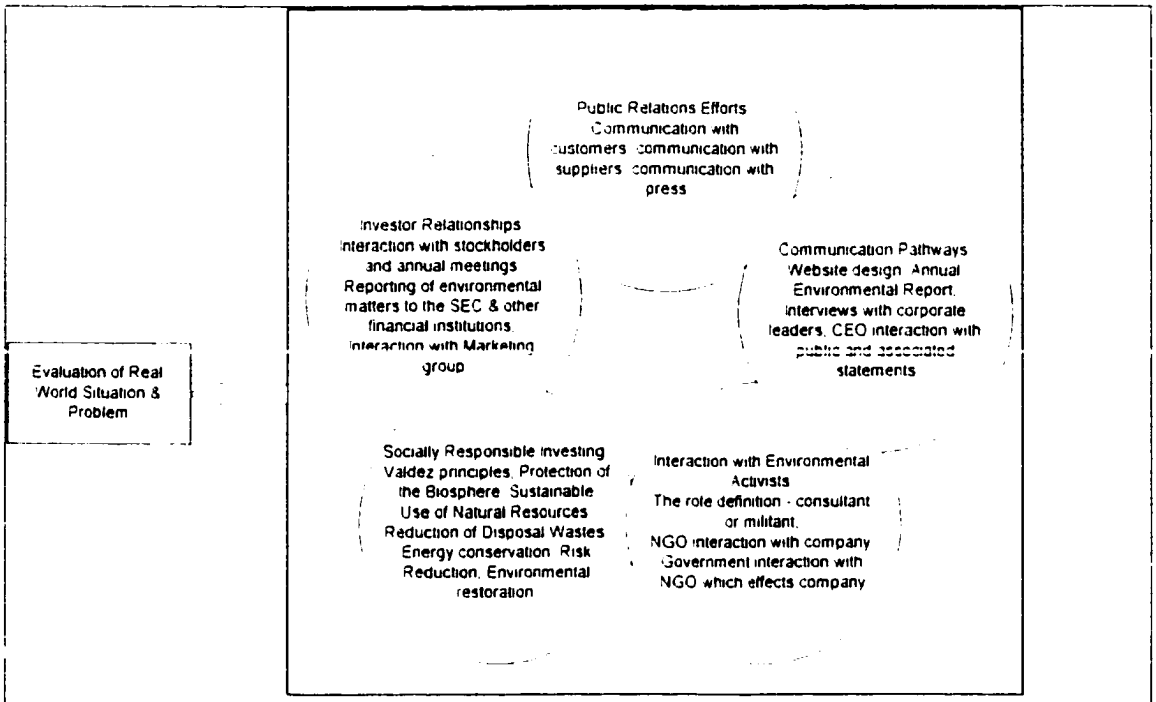

Figure 5.6 Business Marketing Aspects
These are the parameters that the marketing section of the company should consider when making environmental decisions

Marketing involves public relations; investor relationships; communication pathways with customers, the public and investors; and interactions with environmental activists. Note in the figure the potential impacts that the marketing process has on the decision support system. The company must interact with several groups in order to survive. One method to address these needs is the company website, which can communicate its environmental policy, provide interaction with the consumer and provide statements by the company leadership on environmental matters. As noted in Hoffman's work, interaction with environmental activists is also important. Non-Governmental Organizations

(NGO's) inform the public about their beliefs on how companies should function in the environment. Businesses need to communicate with activists as well as investors, who are becoming socially responsive investors. In addition to socially responsible investors, the government, through the Securities Exchange Commission, is also requiring the disclosure of environmental liabilities (White, 1997). Therefore, the marketing group needs to incorporate these requirements when disclosing this information to the public as well as the company investors.

The media may also have a large effect on the public's perception of the company's value; therefore, the environmental engineer needs to communicate what the company environmental liabilities are in a way that the public will understand. This communication technique requires the engineer to move away from direct calculations and toward more graphical and less technical methods of communication. Again, this is an aspect of communication that managers stress should be emphasized in engineering education.

5.3.8 Communication and Coordination of Engineering, Finance and Marketing

The three areas of expertise that make up the knowledge base of the company are the engineering, finance and marketing sections. These areas must communicate for the company to meet its goals and vision. Communication needs to occur in the following ways:

1. The engineering section should utilize their skill in calculations and visualization to help the business partners understand opportunities to lower company expenses for environmental expenditures while improving the environment. This is typically found in the process side of manufacturing, but there are methods to reduce the cost of compliance through an environmental management system as well as more efficient end-of-pipe treatment. The biggest improvements can be made in process and product redesign, with a view toward sustainable development.
2. The financial section needs to communicate the impacts of the environmental engineering changes. Companies typically utilize project costs as a basis for decisions. In the future, the company will need to review all of the costs and impacts shown in Figure 5.5, including life cycle costs. In Europe, this has already started with the Eco-Accounting requirement, which may be a good model for industry. An example is the Interface Carpet Company (Malin, 1999). The company is based in Kennesaw, Georgia, and leases carpet rather than selling to commercial consumers. The concept is to lease carpet to a company and when the carpet has reached it's useful life, it is returned to Interface and replaced. This has resulted in a new market niche for the company while significantly increasing its profits. The engineering and financial sections needed to work together to allow this to occur.

3. The marketing section is the communication pathway with the outside world. They can help the engineer understand the relationship between the investor, final consumer and the company's decisions regarding the environment. If companies are to reach sustainable development, they must coordinate actions of the environmental engineer and the outside world. This will be accomplished through the marketing section.

5.3.9 How Communication Can Occur

How can communication between these three business sections or areas of expertise occur? One of the best methods is for management to support and endorse the interaction. This will result in the environmental engineer moving from only resolving waste issues to becoming part of overall planning. An example of this type of interaction is shown by Kodak, where environmental planning is now part of the overall planning effort (Demma, 1999) and the company has identified an environmental vision as part of their planning effort.

The planning effort will then be incorporated into the overall tactical planning. This will typically occur through line operations, where the engineer works with manufacturing to ensure the company vision is accomplished.

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5.3.10 Models for Decision Support Systems

The next step in developing a dynamic decision support system is to understand how decisions about the environment are made. In the past, companies made environmental decisions to stay within regulations and limit expenditures. However, the survey indicated that experts make decisions differently. They look for solutions which not only meet but exceed regulations and attempt to implement actions which will add to the bottom line while protecting the environment. For the individual to accomplish this type of decision, they must understand how experts make decisions and how, within the environmental framework, decisions must typically be made in a more expeditious manner. Work by Klein and others in naturalistic decision-making shows how decisions are made in a real world setting. Their studies indicate that by utilizing naturalistic decision models in both teaching and training, decisions can be made more quickly and can lead to greater productivity throughout the learning process.

Next, three different models are reviewed for the environmental decision making process (Figure 5.7):

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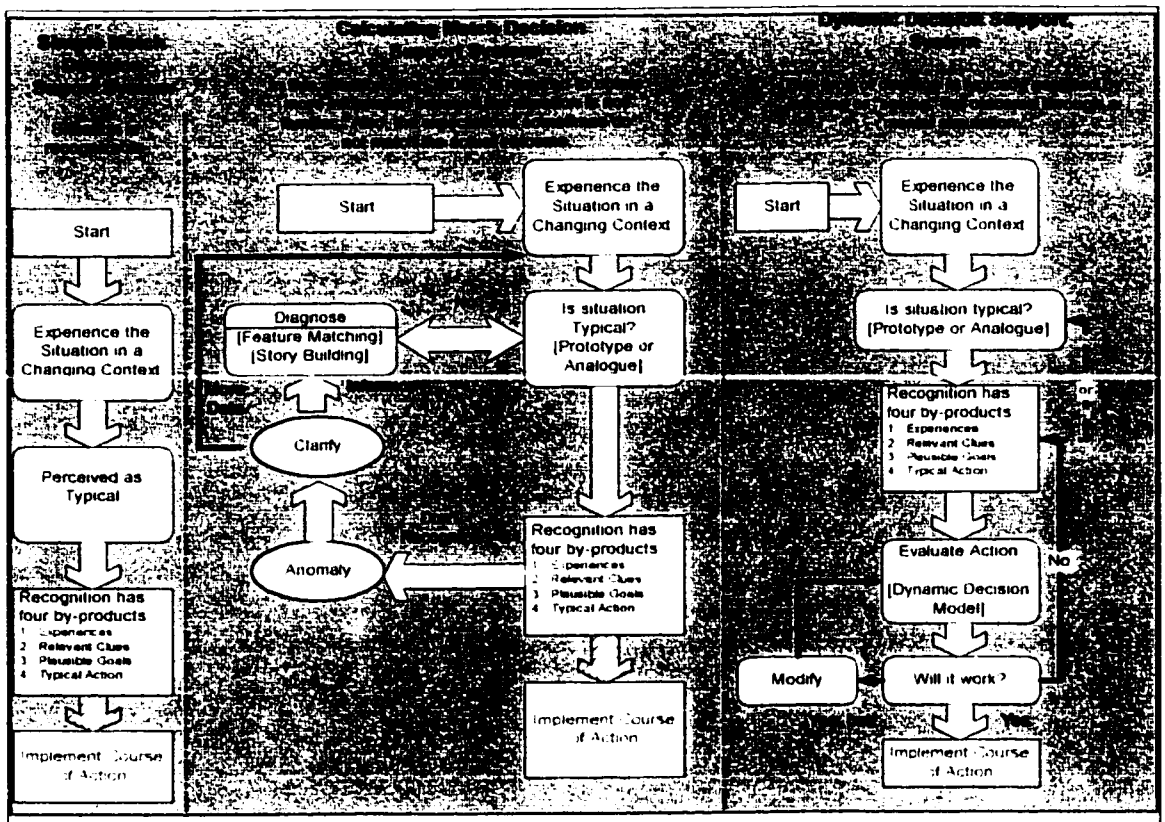

Source Adapted from Klein 1999

Figure 5.7 Three Models of Environmental Decison Making
How decisions are made by experts in the environmental field

In the simple match, the expert recognizes the problem and utilizes experience to solve the problem. This is typically used with problems that have been seen previously and where a suitable solution was found.

In the calculated match decision support system, the engineer recognizes parts of the problem and associated solution, but does not have a complete picture or solution to the problem. The engineer will then use mental iterations to solve the problem using several of the simple match solutions in different combinations.

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The third model is the dynamic decision support model, where the engineer will utilize a mental simulation or visualization process to solve the problem. The engineer will recognize the problem and, using a mental model, try to predict several outcomes. If the mental predictions appear to work, based on the engineer's experience, then they will implement the decision. However, if the pieces do not fit together, the engineer will change the assumptions and try a new mental simulation.

An example incorporating the three decision models is provided in the following scenario:

> This example is based on a metal finishing shop. The company has a goal to become a company that supports sustainable development. They also have a goal to reduce the amount of expenditures as they relate to the environment. As shown in Figure 5.8, the metal finishing shop has several methods to operate a nickel plating line. In order to achieve these goals, the engineer will utilize the three methods of making decisions as outlined in Figure 5.7.

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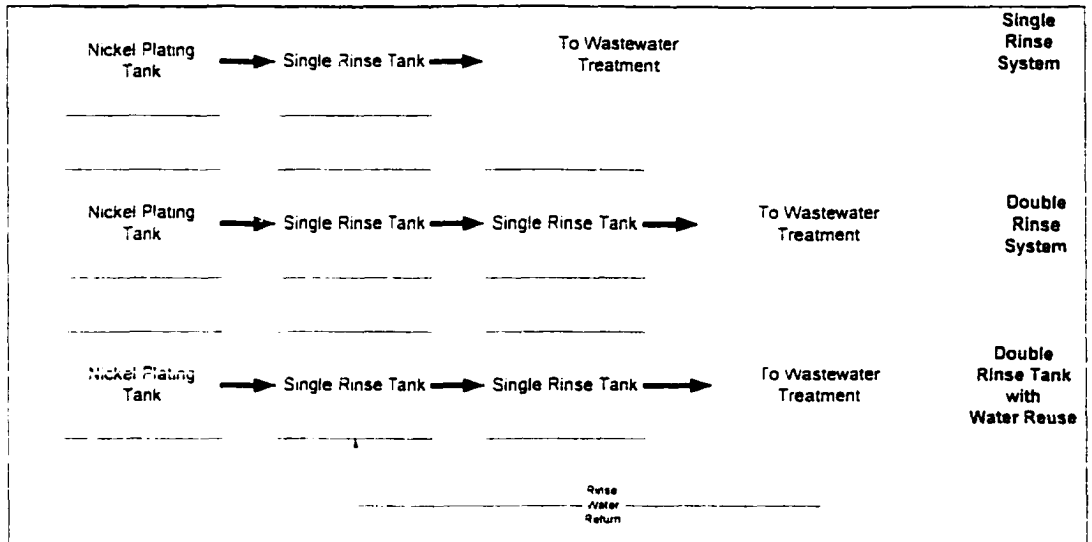

Figure 5.8 Metal Finishing Example
This figure shows the different types of decisions that could be made for an environmental problem at a metal finishing operation

The first problem to be addressed is a quality issue. The amount of rejected parts being plated on the nickel line has significantly increased. The nickel plating bath is where the nickel metal is placed on the part. The existing system is a single rinse tank operation. The engineer has recognized that a metal finishing process is having problems with a rinse water system. The engineer tests the water quality and finds that the total dissolved solids are too high in the rinse water. There are several solutions to this problem:

1. The first solution is to increase the fresh water rinse flow. This will remove the contaminants but increase the wastewater flow.
2. The second solution would be to investigate why the rinse water is becoming contaminated. The engineer discovers that the carry over of

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the process tank solution into the rinse water has increased due to a decrease in the dwell time to allow the part to drain. This is due to the operator's understanding of making production quotas. However, due to the loss of product quality, the rinse water quality decrease is actually decreasing productivity.

3. A third solution would be to review the entire process and investigate if there were other pathways to improve both productivity and rinse water quality.

Using this example, each decision method can be illustrated.

5.3.10.1 Simple Match Decision Support System

In the simple match model, the engineer will recognize a problem and determine a solution based on past experience. The less experienced engineer in this case would probably choose the first solution. This solution will immediately solve the water quality problem. However, it will also cause additional problems in the long run. The first problem will be the wastewater treatment facility's hydraulic and treatment capability. The company is required to stay within compliance for their wastewater permit. This is a federal requirement under 40 CFR 433 and can lead to company and personal liability if the permit conditions are not met. By increasing the rinse water flow, the rinse water will become cleaner for the

product line and aid in better product quality. However, the wastewater system is now required to treat a much more dilute solution, resulting in a less efficient treatment system. The less efficient treatment system will increase the cost of wastewater treatment. In addition, this solution will increase the water flow into the facility, thereby wasting a valuable resource in treated incoming water as well as increasing the cost for raw water requirements.

The engineer could also use this simple match technique in another way. If the engineer had more expertise in this area, he or she would have recognized that increasing the rinse water flow was a temporary solution. The engineer would recognize that the process solution was getting into the rinse tank, contaminating it and causing quality problems. Therefore, he or she would look for a way of preventing the solution from getting into the rinse tank by draining the part in a more efficient manner. Either solution of increasing the rinse water flow or draining the part more efficiently would work in the interim to solve the quality part problem. However, the second solution of draining the part more efficiently would provide a more permanent solution. This solution would be part-specific and not solve the problem with other parts or solve the overall rinse water quality problem.

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5.3.10.2 Calculating Match Decision Support System

As shown by Figure 5.7, the Calculating Match Decision Support System will review several solutions. Again, the engineer will try to meet company goals to be more efficient and an environmental leader. In utilizing this decision support system, the engineer is aware of the problems associated with the cost of redoing the parts due to communication with the finance department. They have shown the engineer the effects of reworking the part. Essentially, the part was plated for free the first time through but needs to be plated again, resulting in a negative profitability for this project because the part has to be reworked.

The engineer then attempts a different solution by uniting a combination of past experiences. The engineer is aware that the company wants to be more environmentally conscious but does not know how to achieve this goal and at the same time solve the rinse water problem. The engineer's experience would provide him with knowledge of the rinse water effects of two tanks in series. By placing a second rinse tank in the process line and having the rinse water flow backwards to the product flow, the rinse water can be reduced while at the same time increasing the water quality within the rinse water tank. In addition to this solution, the engineer realizes that the rinse water quality is determined by the total dissolved solids. By utilizing a simple conductivity meter in the final rinse tank, the engineer can save water while automating the rinse water system.

Water savings will result by controlling the rinse water coming into the tank based on conductivity. The engineer is utilizing experience while also trying to predict what will happen in the future. Not all of the parameters that can affect water quality are known, such as part draining or part carryover, but by incorporating all of the different attributes of the problem, the decision support system will help the engineer visualize the problem.

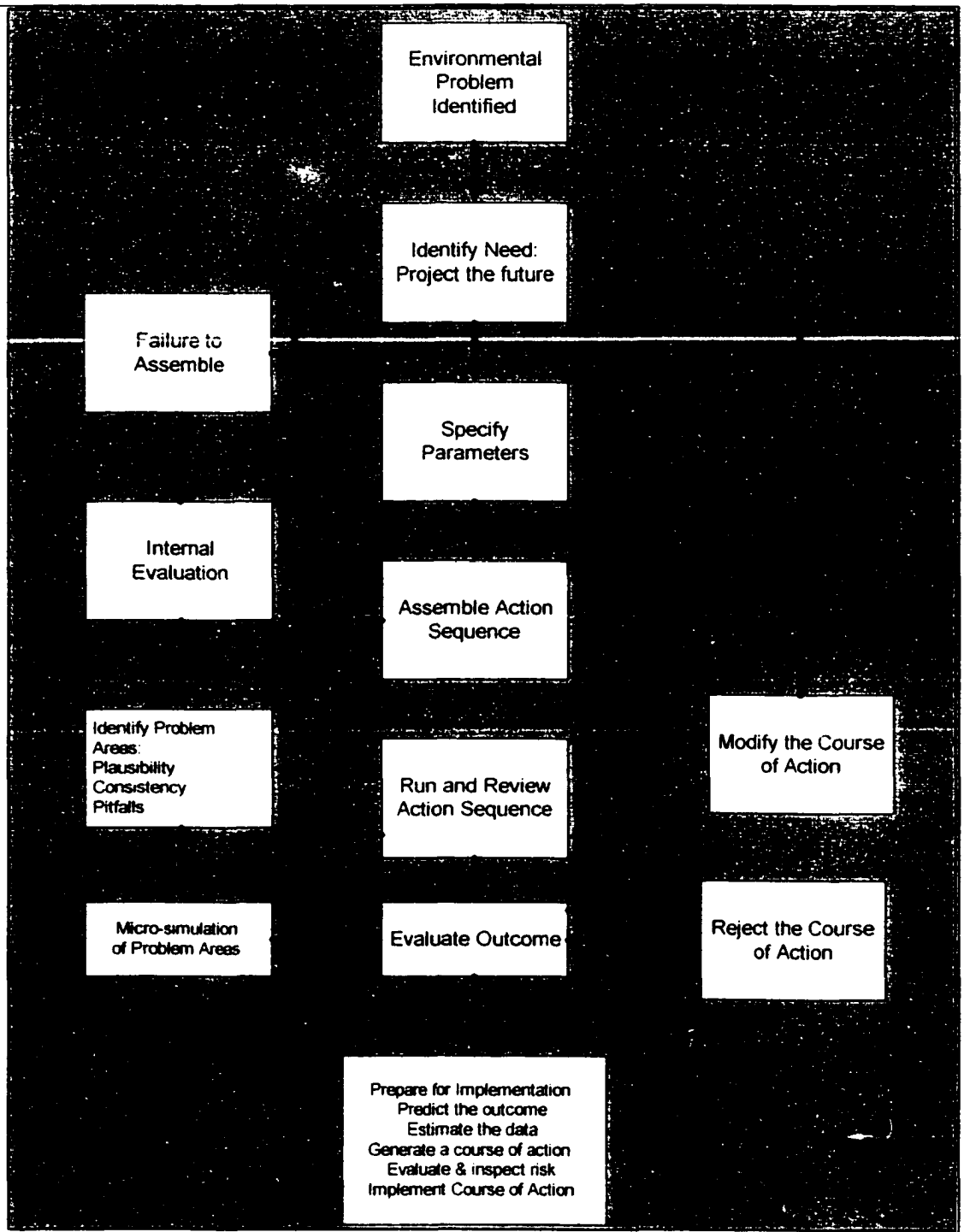
5.3.10.3 Dynamic Synthesis Decision Support System

The third decision model is the Dynamic Synthesis Decision Support System. This system requires the most expertise of all three of the decision support systems. In this model, the engineer will try to incorporate the business, marketing and engineering factors within the company. The engineer will start with the environmental matrix and determine where the company wants to be within the planning period. The engineer will then discuss these goals with the management team and what they mean from a financial and marketing perspective. Once these goals and visions are defined, then the engineer will utilize his knowledge to determine the best course of action.

The rinse water quality is set by the total dissolved solids within the rinse water tank. By designing the system around this parameter, there are several designs which can be envisioned. The first was determined in the Calculating Match

Decision Support System. In this decision model, the engineer developed the double rinse tank system. However, marketing would like to have a system that promotes the saving of water. This will help the marketing department sell how the company is sensitive to the environment. The engineer then tries to envision where this source of water could originate. The two locations would be from limiting the amount of water into the system or reusing the water that originates from the wastewater system. Limiting the amount of water will not solve the problem because of contamination build up. Therefore, the wastewater system needs to be reviewed to determine the best procedure to remove the contaminant of concern (nickel metal) while at the same time reducing the amount of water consumption. The engineer would then use this same process to help in recovering and reusing the nickel metal, which ends up in the wastewater sludge. In addition, the engineer would then determine the most likely method to reduce the toxicity of the overall process. This thought process can continue throughout the entire procedure.

A detailed view of this process is shown in Figure 5.9. As shown by this figure, there are several locations where the idea for the solution will go through iterations. This allows the engineer to make sure that when they are solving one problem, they are not creating another. The engineer is also able to help the other financial and marketing team members use this type of decision making to visualize how these changes will be interpreted by the investor and consumer.



Source: Adapted from Klein, 1999

Figure 5.9 Dynamic Decision Model

How an expert will make decisions without prior knowledge of a solution

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5.4 Why the Dynamic Decision Support System Assists in Providing Better Solutions

Figure 5.10 shows the resulting decision support system of putting all of these ideas together, which provides a summary of the concepts. This is similar to the process shown in Figure 5.3, but provides more detail. At the start, the company determines their position on the Management matrix (Table 5.1). This will assist the company in determining how to react to strategic decision requirements. The next part of the decision support system is the realization of the "real world" problem. The problem is identified through interaction of engineering, finance and marketing in the company, as noted in Figures 5.4 through 5.6. These three different sections of the company make up the "collective knowledge base." Once the collective knowledge base has defined and identified the problem, the engineer and business groups will utilize the situational decision support system. This is made up of three decision models with increasing levels of systems involvement: (1) simple match, (2) calculating match and (3) dynamic synthesis and is outlined in Figure 5.7. Increasing expertise is needed to utilize each of these situational decision models.

Once a decision is made, the company will proceed with allocating and deploying the necessary resources. This will include a portfolio of outcomes from the decision models, what resources are required to implement the decision and the

tactics of how these resources will be deployed to solve the problem. The last stage of the model is the transfer of the tactics to the operations section of the company for implementation. This will provide feedback about the aspects of the real world problem. These last two processes will provide additional information and evaluation of how the problem was solved or what new problems arose because of the implementation of the solution. This feedback will continue back to the definition of the real world situation and problem definition. The collective knowledge base will continually redefine the problem as the context of the business environment continually changes.

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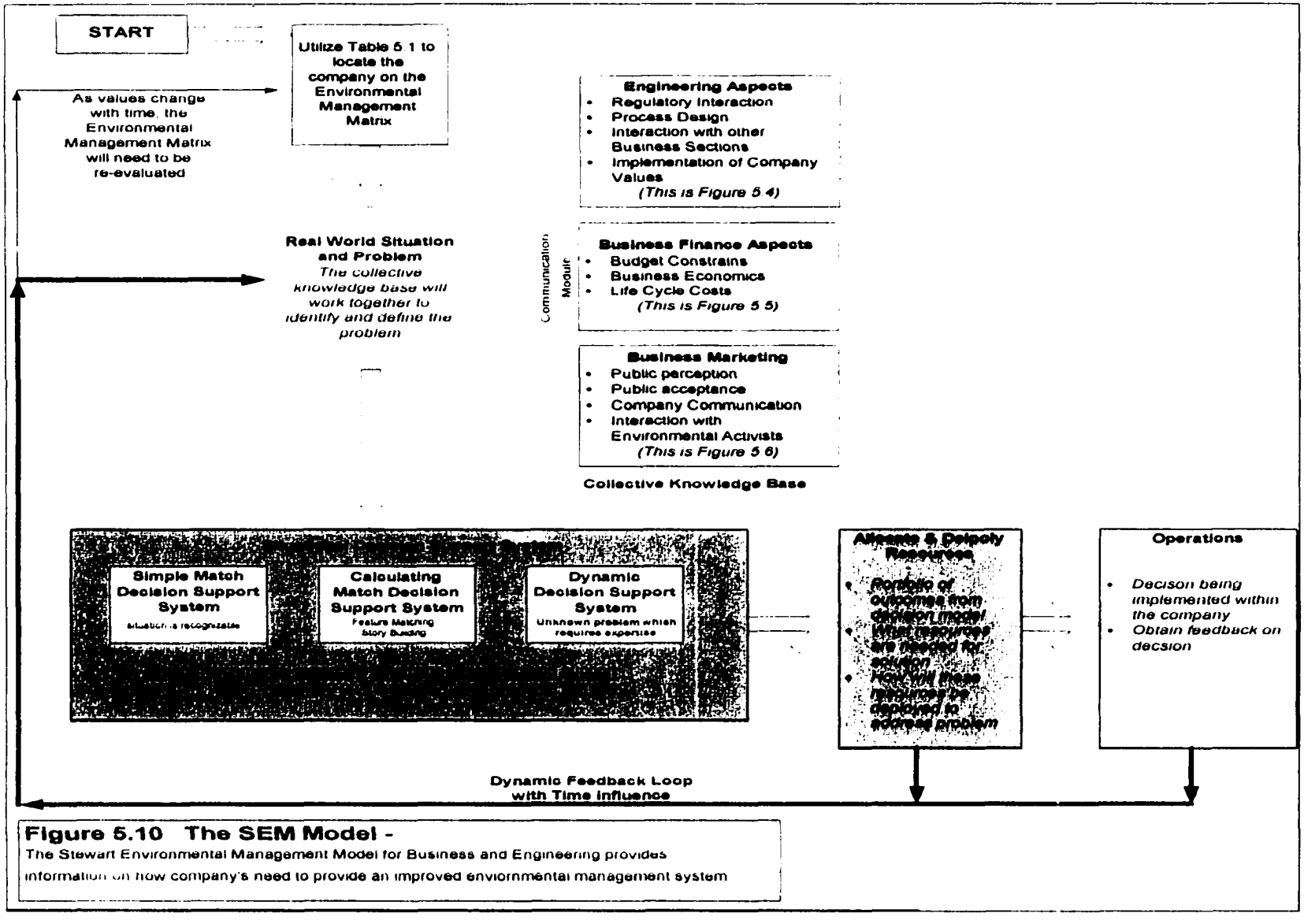

Figure 5.10 The SEM Model -
The Stewart Environmental Management Model for Business and Engineering provides information on how company's need to provide an improved enviornmental management system

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Note how this process might be incorporated into engineering education. Engineering education needs to begin to define a broader context of the problem and also define how experts solve problems in the manufacturing setting. This process will assist engineers in learning to define problems more comprehensively, not narrowly in an "engineering analysis mode."

5.5 Why Will Engineers Be Involved in Management

As shown in the decision support system, engineers will be crucial to the overall success of the future of manufacturing. In the past, the engineer was often viewed as a technician, but in the future will need to be part of the overall strategy of the company. This is due to the specialized knowledge of the environmental engineer and how their expertise will be required to interact with the business side of the company. This is being evaluated and implemented by management due to the liability of wrong decisions and the rising cost of environmental management. However, in the future the engineer will provide the basis for future cost savings and innovations, which will add significantly to the bottom line.

One of the features of this research is how it shows the increasing trend of environmental engineers to be involved in management, and it informs engineering educators and students about areas of management which should

be stressed. For example, for engineers to relate environmental choices to finance and marketing, they must know something about these areas. Unless students are exposed to these areas in their education, they will be ignorant of them and unable to participate in the cross-functional decisions called for by engineering leaders.

In addition to presenting new concepts for decision support systems, Chapter Five presented case studies which showed the potential cost savings associated with better environmental management systems. For example, Interface Carpet found a new way of providing a product and service that supports sustainable development. This new method of delivering carpet in business has also provided for a more profitable company, with a recyclable product and higher margins for the product. Other industrial sectors can achieve these same or similar results if management will include engineering in strategic and tactical management.

The Dynamic Decision Support System provides for a broader, more comprehensive view, which is consistent with "systems thinking" and "organizational learning" techniques for improving productivity. It is also consistent with Deming's principles, especially looking at the whole picture.

Based on this research, several aspects of engineering education should be improved to respond to this new paradigm:

1. Engineers will need to learn to define problems more comprehensively, including the business aspects of the company.
2. Engineers should learn about real world problems in their training process, not simple problems of "analysis" in the technical sense.
3. Better communication will need to occur both ways within companies: engineers to management, and vice versa.
4. Engineering schools will learn to consider finance and marketing within their curriculums as new requirements for engineers.
5. Engineers need to present information in a more comprehensible manner, including a more systems approach to problems.

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Chapter Six

Conclusions and Research Needs

6.0 Decision Support System

The Stewart Environmental Management (SEM) decision support system, which combines engineering and business aspects, will allow industry to achieve environmental leadership while increasing profits. This decision support system will also support the growing trend of sustainable development within companies. Sustainable development in this dissertation is defined as the process of making products or providing services with fewer critical resources, releasing fewer contaminants, containing fewer toxics and making products that can be recycled while offering the same quality at an equal or lower cost (Wallace, 2000). A good example of this ideal of sustainable development is the Interface Carpet Company, where they have shifted from selling carpet to leasing carpet. This allows Interface to reclaim the carpet, and reduce their overall costs and impact on the environment.

Chapter Two reviewed the current literature of decision support systems and the lack of systems that address the changing context of internal and external aspects under the current business setting. The changing context of aspects was identified by the Enterprise for the Environment (Ruckelshaus, 1997a,

1997b), which stated that regulatory and business sectors will need to change in the future to advance the protection of the environment. Hoffman (1996, 2000) provided information on how corporations have changed in the past and where leading companies are moving in the future from environmental management to environmental strategy. The literature review also presented the natural decision making process (Klein, 1994, 1999) which provides the model for the decision support system developed in this dissertation.

The Mini-Delphi survey provided original information on how companies view the current status of the environment and how they view the future of business and engineering aspects. There was very good agreement among the experts that companies needed to incorporate engineering aspects of the company into the overall management of the company. The Mini-Delphi provided information on how engineering sections in the past have been used to solve the "end-of-pipe" problem. However, leading companies are beginning to move toward incorporating engineering functions in the overall management of the company, allowing the company to pursue a goal of sustainable development through the design of products that will better serve the customer.

The experts also felt that the world is going to change dramatically in the next 10 to 20 years. This will affect the way business is conducted in the future and will

require engineers to become more aware of the business constraints and how to modify engineering projects to meet the goals of sustainable development.

The SEM decision support system also moves away from the traditional static approach to decision making to a more dynamic approach. The SEM decision support system starts with the unique Environmental Management Matrix provided in Table 5.1. This matrix and decision support system will be very important to the environmental engineer in the future because of time constraints and the reality of a constantly changing context of the problem in which these decisions are being made.

6.1 Results and Findings

This dissertation provided information on the trend of involving the environmental engineer more in strategic and tactical management roles, which will help the company achieve environmental compliance. This growing trend was identified in both the literature search and the Mini-Delphi. A technique for adding the additional involvement of engineers is provided by combining the engineering and business aspects with a decision support system. This involvement by the engineer will enhance the ability of the company to reach the goal of becoming "greener" in the eyes of the public and stakeholders of the company by guiding the marketing aspects of the company.

The dissertation traced the decision support system from the simple, or static system, to the dynamic version. The static decision support system does not have a feedback loop from the initial alternatives to the final solution. This approach does not allow the decision being made to be modified with the changing context of the environmental problem, which was identified in the literature search and the Mini-Delphi survey. In order to resolve this problem, the Naturalistic Decision Making (NDM) process was modified to fit the environmental setting of a company. The NDM utilizes varying degrees of expertise in the decision process.

The SEM decision support system also identified the beginning context of problem solving development (i.e., the environmental management matrix in Table 5.1) and how to use the knowledge base of the company to solve environmental problems, including the engineering, financial and marketing aspects (which are identified in Figures 5.4 through 5.6). The combination of the engineering, financial and marketing aspects of the company is one of the new concepts developed in the SEM decision support system. This will allow the company to search for innovative methods of meeting their environmental goals while improving the overall profitability of the company.

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6.2 Evaluation of this Dissertation

The originality of this work lies in the combination of the business and engineering aspects of the company. The environmental engineer will be crucial to the success of a company providing manufacturing services where sustainable development is a value to society. The engineer is required to provide the process and design changes necessary to technically meet the requirements of any environmental project.

The process design changes proposed by the engineering section of the company will need to be defined in concert with the financial and marketing sections of the company. This is the collective knowledge base and communication pathway that is defined in Figure 5.10. The engineer will need to communicate the constraints of the project to the business sections of the company. The financial and marketing sections will need to communicate their constraints to the engineer to ensure the viability of the goal of supporting sustainable development.

The research showed a paradigm shift within management of companies. This paradigm shift was identified in the Mini-Delphi as a goal for leading companies. It is this shift from the traditional engineering project management to a more dynamic approach that differentiates the leading environmental companies. This

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different approach includes the environmental engineer within the business aspects of the company. In the past, the environmental engineering aspects were identified to treat the "end-of-pipe" problems. The new environmental engineer will provide guidance to the overall company with regard to environmental matters that will help companies realize their goal of sustainable development. In addition, the engineer will be required to understand the different costs as outlined in the financial section of the decision support system. This will be combined with the marketing and communication aspects of the company.

6.3 Contributions of this Dissertation

6.3.1 Literature Review

The literature review provided information on the past and current status of the environmental engineering field as it relates to the business aspects. This literature review provides a compilation of ideas that allow the reader to assimilate the importance of combining the engineering and business aspects of the company. The literature search also provided information regarding the decision support system, from the traditional system to the dynamic system. This new dynamic system was highlighted due to the innovation of expertise utilized in

the decision support system and the application of this type of system in environmental decisions.

6.3.2 Mini-Delphi Survey

The Mini-Delphi provided original information regarding the opinion of experts and their prediction on how environmental management systems will be utilized in the future.

One of the first contributions of this work is the Mini-Delphi of the environmental experts, which provided new information on how these experts viewed the environmental management system that is currently used today and how it will change in the future. This information included:

- The global shift towards increasing environmentalism;
- Prediction that the public will be less moderate in the future with regard to environmental regulations and there will be more public pressure toward company compliance in the future;
- Requirement that management be more participatory in the future, both internally and externally, with regard to environmental matters;
- Finding that environmental management systems will be very important in the future;

- Trend that while profits are still important, some companies will place consumer want satisfaction ahead of profits;
- Reality that Non-Governmental Organizations will have increasing effects and involvement within companies in the future;
- Trend where EPA will move from the command and control to a more cooperative method of enforcement;
- Trends towards shared decision making between engineering and business management.

6.3.3 SEM Decision Support System Contribution

The SEM decision support system and the Environmental Management Matrix (Table 5.1) that were developed are the major contributions of this dissertation. The contributions within the SEM decision support system are highlighted below:

- As shown by the literature search as well as the case studies, companies are beginning to trend toward environmentally sensitive management behavior and are attempting to achieve sustainable development. This research provides a dynamic decision support system to assist companies in reaching their environmental goals. This decision support system will provide the technique for management to implement the necessary interaction between engineering and business aspects of the company.

- This research provides information on why it is very important for the environmental engineer to understand the interaction of the business system and become involved in the management of the company. The Mini-Delphi identified several leading environmental companies and how they apply this concept. The literature search provided examples of how the involvement of the engineer will benefit the company. This benefit is added profitability as well as a better corporate image. This decision support system highlights the change from meeting regulations and "end-of-pipe" technologies to "sustainable development." This change in how a company interacts with the environment will not occur without the business aspects being satisfied. Therefore, the environmental engineer must take into account not only the engineering aspects, but also the financial and marketing aspects of any project. This will require better communication between these business sectors within the company.
- The literature search and the Mini-Delphi indicate how the company needs to makes a conscious decision where it wants to exist in relation to the environment. This will determine where the company will go in the future as it relates to the environment.
- The environmental management system matrix also needs to take into account the ethics of environmental engineering. The long-term effects of a decision made by the environmental engineer can have generational consequences.

- Once the company decides where it will exist in relation to the environment, the company will need to understand how decisions are being made by engineering experts. The SEM Model utilizes the engineering expert, which has three different choices as developed by Klein (1996) with respect to making decisions. The simple match will be utilized the by the less experienced engineer, with the most experienced engineer utilizing the dynamic synthesis decision support system.
- The SEM decision support system will allow a more flexible and dynamic decision making process that will respond to the changing context in which environmental decisions are being made.

6.3.4 New Approach to Educating Engineers

This research indicates that engineering education should also be modified in the future. This concept is based on the need for the engineer to become more familiar with aspects of the business world. Companies as well as governments are searching for ways to reach sustainable development. This is a goal that is being dictated by society. In order for this to occur, engineers will need to understand the financial and marketing aspects of companies. At the present time, most environmental engineering curriculums do not include this type of education. While business aspects can be learned once the engineer leaves the

university system, it would be more beneficial to the engineer and companies as a whole to include these topics as ideas within the curriculum.

6.4 Critique of this Dissertation

The criticism of this dissertation would be the inability to test the SEM decision support system in real practice at this time. Some companies are attempting to combine business and environmental engineering aspects of the company. The SEM decision support system combines, for the first time, these different company aspects. The SEM decision support system was developed from information found within the literature search and the Mini-Delphi survey. Therefore, this particular dynamic decision support system needs to be tested completely within the business setting.

6.5 Future Research

Future research in this area would be to find a company willing to implement this decision support system and monitor the results. All evidence points to the idea that the approach adopted by companies can become more environmentally conscious while at the same time improving profitability. It is critical to involve the environmental engineer in the management system of the company. The SEM Model will provide the required decision support system. The SEM decision

support system can also be applied to companies worldwide. Asian Rim and European companies might benefit from this research, as this financial and management analysis associated with environmental decision making is already being required as part of the Eco-Auditing requirements of the European Union.

6.6 *Toward the Future – Emergence of a New Paradigm*

The trend of the future, as identified in this dissertation, is the emergence of a new paradigm. This is summarized below:

1. The world of environmental regulations is changing at a very quick pace, requiring decisions to be made in a changing context that will include both rapidity and complexity in the decision making process. This changing context requires a new decision support system. The SEM decision support system is a start to answering this need.
2. The field of environmental engineering requires expertise in not only the process engineering aspects, but also the regulations and laws that govern how problems can be addressed, and how the engineer must address the interaction of company stakeholders, outside forces such as non-governmental organizations and environmental activists. Changing from environmental management to environmental strategy will internalize this decision-making process within the company. By utilizing the

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company knowledge base, management can change the method of decision making to support sustainable development.

3. This dissertation highlights the future of environmental engineering through the Mini-Delphi survey and the potential for interaction within companies that will include engineering as part of the overall strategic and tactical management groups within the company.

The complexity of the working setting and the rapidity of decisions that need to be made will move decision makers to find a new method of implementing decisions. The SEM model will help companies identify how this can be accomplished.

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Appendix A

Mini-Delphi Survey & Results

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A.1 Introduction to the Survey

The following information is a compilation of the answers to the Environmental Decision Making Questionnaire. This questionnaire was provided to the list of experts provided in Attachment A.

A.2 Expert Background:

There were 15 experts asked to participate in this survey. Eleven experts did participate in the survey. All of the experts had a college education and additional specialized training. Two-thirds of the experts had an advanced degree of some type, either engineering or business degrees. All of the experts were in upper management within the company and in direct charge of environmental matters. The company size ranged from a small company defined as revenues less than 2 million in sales to Fortune 100 companies.

1. *What position do you hold within your corporation?*

   The answers vary with each individual. In some cases, the expert was a Vice President or Senior Vice President. In other cases, with larger companies, the expert was in charge of environmental matters at a large manufacturing facility and held the title of Environmental Health & Safety

Manager. In all cases, the expert was very familiar with the state of environmental matters and how they affect the overall company performance.

2. *How do you briefly define "environmental management system" (EMS)?*

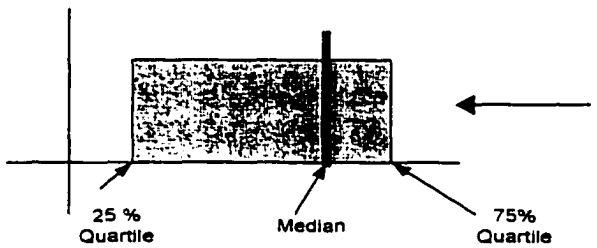
EMS has as a foundation the total commitment to meet all regulatory rules and requirements, both locally and nationally, and to commit the resources necessary to meet these objectives. EMS is part of the overall management system that includes beliefs (value judgments), resources, planning activities, roles and responsibilities, and practices and procedures to achieve these goals and implement the company policies at a reasonable cost. EMS will eventually become a competitive strategic advantage in business. This competitive advantage will include the integration of environmental costs & benefits into a company's business/market plan.

The specifics of an EMS system are along the lines of Plan, Do, Check, Act (PDCA) that assures the business and significant environmental aspects and impacts are properly managed to assure regulatory compliance and minimize potential for negative environmental impacts. This would include the integration of environmental and safety aspects of the manufacturing process. It is important to have constant improvement

within the environmental management system. The EMS would also incorporate the ISO 14000 guidelines and have "how-to-modules" and "tools and templates" within the management system.

The overall goal of the EMS is the selective combination and application of disciplines drawn and blended from business, hard science, social science, politics and ethics, that are used to maintain or improve ecological balance.

3. The next question was asked in three parts:
   a. How does an environmental management system affect business decisions today within a business management system?
   b. How has the method of decision making changed in the last 10 years?
   c. In your opinion, how will this new direction in environmental management system affect decisions in the next 20 years?



Explanation of the following graphs

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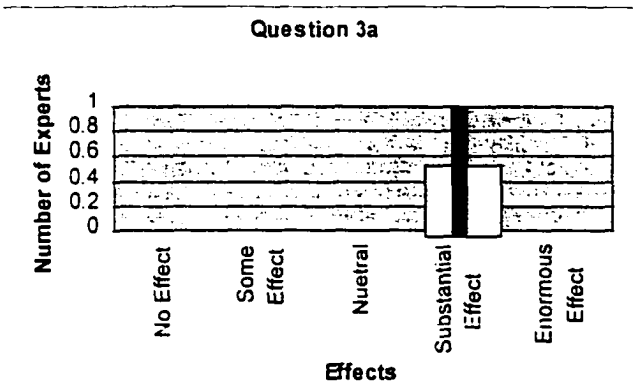

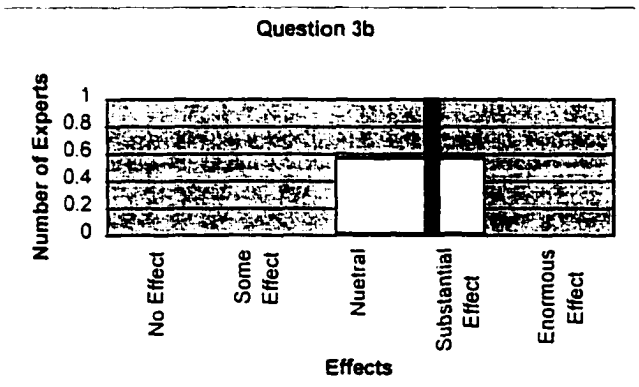

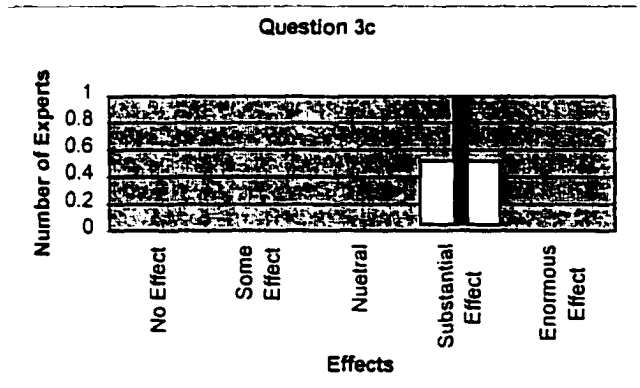

As shown by the above charts, the experts tended to agree that all three statements would have had a substantial affect in the past as well as one in the future.

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4. *As you review your management career over the last 10 years, what is the biggest change that you have noticed in environmental compliance? (e.g., increase in laws, enforcement of regulations, regulatory overload, etc.?)*

Due to the different experts used in this survey, the answers varied considerably. However, they are summarized below:

One of the most important changes that has occurred is the implementation of environmental quality assurance processes (auditing) within business to assess and assure compliance with environmental laws and regulations. This has allowed a shift from a compliance based restrictive system to a management based performance system. This has allowed a higher degree of awareness of corporate social responsibility linked to EH&S issues. Shareholders are utilizing this awareness to shift the focus of a company's environmental management program.

While this has occurred internally within some companies, others have observed an increase in enforcement by regulatory agencies to force non-performing companies out of business. This has been coupled with a dramatic increase in environmental laws and regulations, even with a Republican Congress. There has also been an increase in the use of P2,

multi-media effects, etc. as method of choice as opposed to "command and control." This change has resulted in the realization of the "cost/benefit" analysis, that is, the performance of environmental management for economic reasons rather than being forced by regulatory agencies through "command and control." This can be summarized as a shift from media and political control systems which lead to "fix it at any cost" mentality to more of a risk based economics influenced approach.

5. *How have the values of the corporation changed in the last 10 years with regard to environmentally sensitive issues?*

Values have changed by 180 degrees within the last 10 years. Business has begun to understand the relationship between overall business objectives and environmental issues, which has been driven by customer and public expectations. Stockholders of public companies are also demanding more environmental awareness from companies. Businesses have also determined that bad business decisions regarding environmental matters can equate to a loss of business and shareholder wealth. This not only originates in the form of fines from regulatory agencies, but also from consumer boycotts, such as the one that resulted from the Exxon Valdez incident.

With the advent of more regulatory fines and the increase in the number of violations as well as the amount of the fines, more company managers are aware that the company's actions can affect the bottom line with respect to profits. This has resulted in a more focused approach by the engineering staff of the company. In addition, company management is requiring that the facility and engineering staff take a more proactive approach to environmental management, with a focus on pollution prevention and sustainable development. Marketing departments within companies have recognized that this shift has also provided an opportunity to market the "green side" of the company.

There is also a shift in control from one generation to another. This shift in management control and in companies' overall philosophy has resulted in CEO's agreeing that they need to protect the environment in which they live and the environment that their children will inherent.

6. *Within this same period of ten years, what do you view as the most important achievements within environmental management systems as they relate to business systems? (e.g., better efficiency, effective coordination; responsiveness to public demands, etc.)*

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The overall consensus from the experts was the improvement of measurement systems, which allows for a better understanding of the constraints as well as the opportunities. This consensus included aspects such as encouragement of business management in the process of environmental management; total environmental cost accounting taking into account the costs of existing and future regulations; the environmental engineering staff being consulted during the initial stages of various projects to assist in compiling a final product that will meet the company's strategic goals; and finally, the ability to be flexible in a real time change environment with employee empowerment and the resulting employee responsibility. Employee involvement allows for better opportunities to identify problems and potential opportunities to save additional costs.

7. *What are the biggest obstacles associated with environmental management systems as they relate to a business management system?*

Return on investment (ROI) is one method that many managers utilize to make investment decisions. Environmental management systems have an ROI, but this return is very difficult to quantify. Some managers equate this benefit as an added value, but it is not quantifiable in terms of costs. While the costs of environmental management are easily identified, the benefits are more of a problem. This will likely require the development of more

sophisticated environmental accounting and management systems which can measure the costs as well as the benefits of environmental management.

Another problem that has been identified is the ability to obtain and keep a manager's attention on environmental matters. Most CEO's of corporations do not originate from the environmental side of business. Environmental problems are typically an expense and while reducing this expense helps the company, it is very difficult to maintain a manager's attention on environmental matters, which are not a profit center for the company. The long term views required in most environmental management systems are also in direct conflict with most companies' cultures of short term profits and goals (i.e., the quarterly statement). All of this relates to the costs and resources needed to properly manage environmental systems and the reluctance to spend money.

Another aspect of environmental management systems is personnel. Environmental managers are typically in a science-based discipline. Managers are typically trained in business and finance. Employees are trained to complete specific tasks within the organization and are normally not trained in the sciences. In the past, environmental managers have expected the business managers to "talk their language." Several of the experts have stated that environmental managers need to put the problem definition and

alternative solutions in the context of the total business, including putting it in management's language. In addition, environmental managers will need the ability to discuss this with the entire employee staff as well, which will require more training in communication. Training will allow environmental managers the ability to present the positive environmental strategies as part of the overall business strategy.

One of the biggest obstacles in achieving an effective EMS is the ability to track and interpret all of the different, conflicting and complicated regulations throughout the facility. This typically requires a team effort in order for the EMS to be effective.

8. *As an environmental manager, how do you provide incentives for environmental cost accounting?*

Most of the environmental managers surveyed stated that they provide incentives through recognition activities, which are non-monitory in nature. However, several companies have environmental excellence awards, which then are part of the executive bonus structure within the company. These awards will help with the attention span required for managers to understand the need for environmental management. Along with this bonus structure is a system which requires specific measurable goals and cost accounting to

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show reductions in overall management costs. In addition to overall management goals, some publicly traded companies are now required to monitor, maintain and report on environmental operating and capital expenditures and potential liabilities associated with environmental problems. The incentive program can assist in identifying new methods of liability and cost reduction programs.

Some environmental managers provide incentives through cost savings achieved by a particular project, for example, recycling a waste rather than landfilling. This analysis will take into account all of the various costs as well as reduction of potential fines from eliminating the activity that could cause the fines. This is coupled with the history of the facility to achieve a probability of a fine actually occurring and providing more weight to the benefit side of the management system. Another method is to provide the value of cost avoidance (utilizing the worst case scenario) and then provide the alternative which shows the added value through both potential and real numbers. Part of the added value can be through the lower cost of production or the "perceived" value of the company being more environmentally proactive.

9. *Does your firm provide for full activity based cost accounting? (An example of full activity based cost accounting would be to account for not only the labor*

and materials, but also the overhead, utilities, taxes, insurance costs, fees associated with the activity, the marketing costs, the public perception, etc.)

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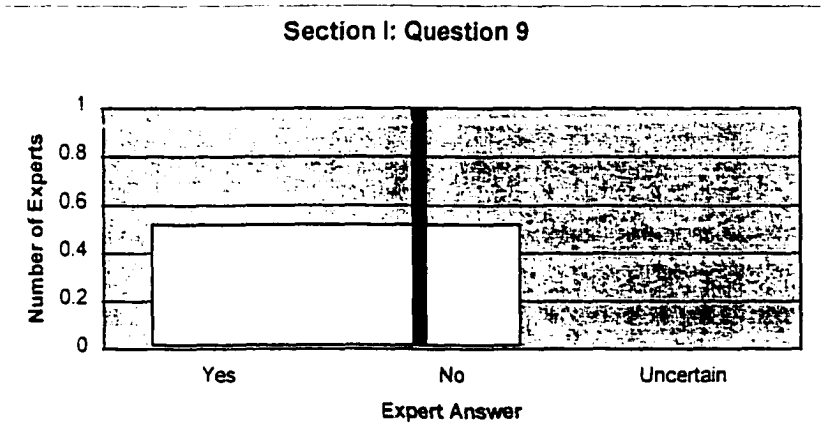
This answer had a "yes", "no", or "uncertain". The answers are graphed below:



As shown by the above graph, there is still a majority of firms that do not provide for total activity based accounting for environmental matters. For the firms that answered yes to the above question, most were involved in European markets, which require as part of the European community an environmentally based activity accounting system. For companies that were not involved in Europe, the firms were very concerned with the cost of production. This cost of production included the items for activity based cost accounting with respect to environmental matters.

10. *Is cost accounting performed on an individual product or is the environmental cost provided in general by a factor relating to sales or other mechanism?*

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Almost all of the experts surveyed stated that environmental costs were a function of sales. Some of the experts have determined these costs on a more specific basis, such as a product line or individual products. I did not find any experts that currently provide environmental costs on an individual product at this time. However, many of the experts were tending to head in this direction in the future.

11. *How do you estimate future environmental costs?*

Most of the experts estimate future environmental costs either on established targets or based on past practices. The estimation on past practices includes the past cost for environmental operations based on the associated production, an estimate of new capital expenditures based on new production requirements, changes in the labor requirements due to updating control systems and subtracting the costs due to new innovative environmental programs. All of the experts surveyed provided at least one year of future environmental costs. In some cases, a one year and five year projection were provided. Some of the experts also separated out the cost for liability. This allowed a more detailed estimation of the risks associated with various projects or products.

12. *To whom do you provide this information to? (e.g., the Board of Directors, the shareholders, the public, company personnel?)*

The experts typically will supply this information to their immediate supervisors or corporate environmental group and eventually the information will go to the company President and the company Board of Directors. A lot of the time, the information will be utilized to communicate with the company shareholders as public as required by the SEC.

13. *If relevant, how does your company achieve an outreach program to either the employees or the public regarding environmental programs?*

All of the experts have some type of mechanism for company outreach. These mechanisms include the publication of an environmental annual report for the public, web-based environmental information about the company; local site facility electronic newsletter; and public relation statements by the PR department, especially on new products or ideas that affect the environmental program. Some of the experts utilize extensive training programs with employees to ensure that they will understand the company philosophy regarding environmental programs and possibly be an informal spokesman for the company.

14. *Does this program reach out to the public; both locally and corporate wide?*

The public outreach programs varied by expert. In some cases, the information was provided on both a local and corporate wide program. This type of program was touting the progress made by the company on various environmental aspects. At the other end of the scale, the information was only provided on a case-by-case basis. This was needed to keep the integrity of the program and to ensure that all aspects of the environmental program were being met. In all cases, information required by regulations was provided, such as those needed in the EPCRA regulations.

15. *Is the possibility of a consumer boycott due to environmental matters a concern to the company?*

In all cases, any type of boycott was a concern to the experts surveyed. However, those with European operations were more concerned due to the new requirements in the European Community. However, in all cases, it was a remote possibility, so while this was on their radar, it was not a large concern.

16. *How would your company respond to a consumer boycott, if related to environmental matters of the company?*

All of the experts stated that they would provide a proactive approach to answer the concerns raised by the boycott. They also stated that science and facts would be utilized to fix the problem and make sure that the fix, both immediate and long term, was appropriate. The experts would also utilize past history as part of the public relations campaign in order to provide the public with information that they might not have in their data bank. The experts also agreed that this would be a time when integrity would be very important. It would require admitting a problem if one existed and then fixing the problem so in the future it would not arise again.

17. *Does your company have measures for successful pollution prevention?*

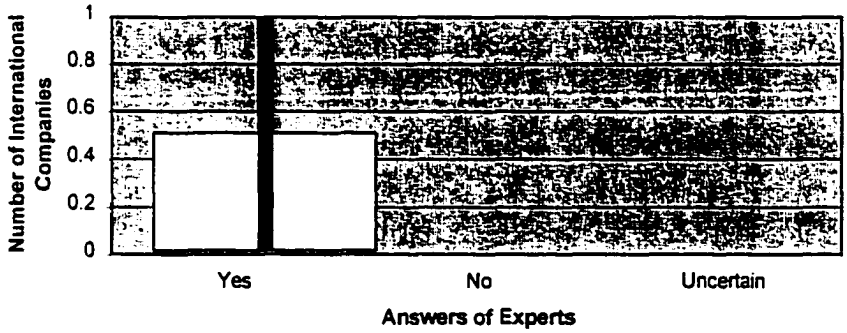
In all cases, the experts stated that their companies institute pollution prevention. In some cases, there were specific measures for pollution prevention, such as the Montreal Agreement for greenhouse gas reduction. Also, most of the companies have programs which recycle or reuse materials that are produced by each facility. In all cases, there are the mandatory requirements for hazardous waste reduction. In all cases, the companies were complying with this section of the RCRA regulations.

18. *Does the measure of pollution prevention relate to a unit of production? What is the unit of measure?*

Typically, the unit of measure is the waste produced against the number of products produced. In some cases, the product produced is a measurement, such as tons or cm^2. In some cases, there have been studies performed which provide for baseline values. For example, in the metal finishing industry there have been values set for the tons of waste produced with a certain type of plating and an associated sales volume. There have also been comparisons by some experts on the amount of tons per year generated and the goals set for reduction of these values, regardless of the production of the facility.

19. *Is your company international?*

Section I: Question 19



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As shown by the above chart, a majority of the companies and experts surveyed have an international component to their business.

20. *If your company is international, do you have facilities that are within the European Union?*

For the companies that have international operations or facilities (8 companies), there are 6 companies which have facilities within the EU.

21. *If your company is within the European Union, is your company participating in the Eco-Accounting and Management Scheme (EMAS)?*

Of the 6 companies that are within the EU, 4 of these companies are participating in the EMAS.

22. *How has the EMAS affected your company's performance?*

The major effects of EMAS have been in product and packaging recycling requirements. The EMAS and EU require that companies provide an emphasis on non-hazardous waste reduction. Out of the 4 companies participating in the EMAS, 3 are or are becoming registered with ISO 14001.

Several of the European sites have already been registered with ISO 14001. The result of these activities is a higher awareness of the environmental management system as well as positive self assessment and positive thinking on a company wide basis. One benefit of the EMAS is the environmental portion of the company is becoming part of the overall business strategy.

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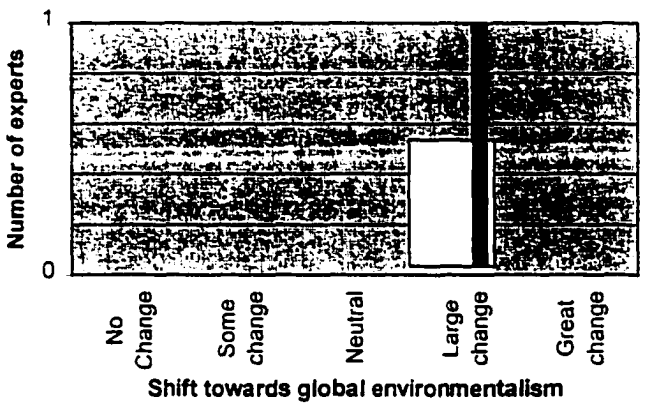
A.3 Section II – Future Trends and Developments

In this section, I asked questions regarding how our experts see the future for environmental management systems. All of these answers are provided in a graphical format.

1. *Do you see a global shift towards increasing environmentalism?*

Section II: Question 1



We have one expert that split his answer between large change and some change, depending on the topic. However, as shown, 7.5 of the experts saw either a large change or great change.

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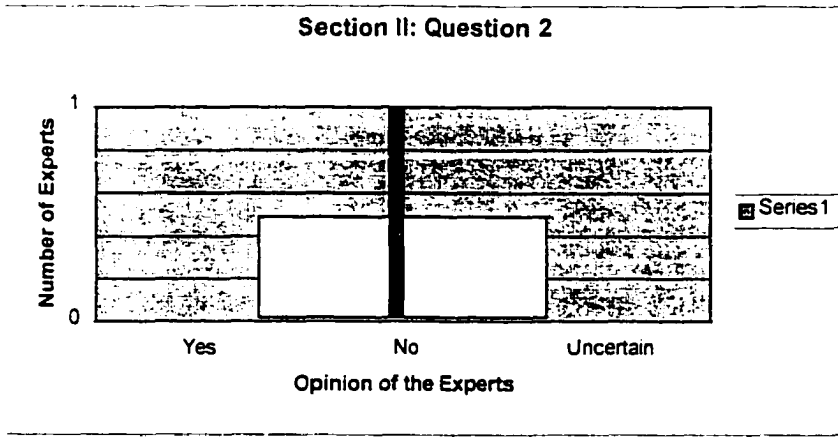
2. *Do you think that the general public is going to be more moderate in the future regarding environmental matters?*



It appears that a small portion of the experts feel that the public is going to be more moderate in the future. However, when combining this with other answers, I summarize that the experts are uncertain how they will interact with the public in the future. While some are being very proactive, it is not certain that they feel the public will be forgiving or understanding when working on environmental matters.

3. *When would you expect the general public to be in a more moderate position?*

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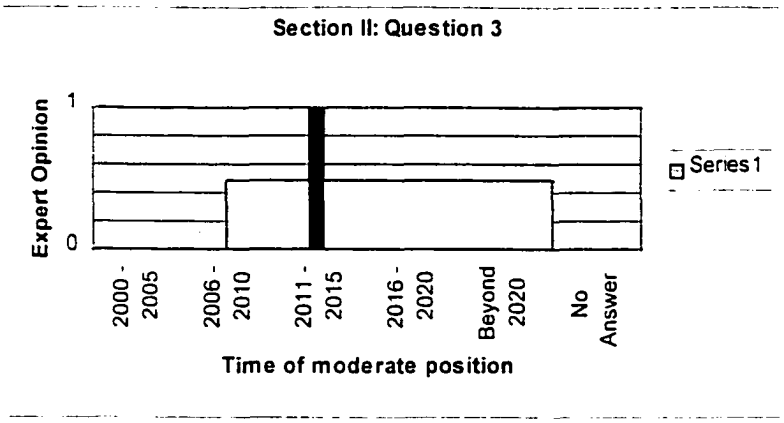

Again, there is not good agreement regarding the timing of this question. However, the majority believe that within the next 15 years (almost 1 generation) the public will be in a more moderate position. This is in agreement with most of the literature on this subject.

4. *Some management experts state that there are three main components in business that need to be balanced: (1) company profits, (2) consumer want satisfaction and (3) public interest. In your experience, which of these factors will be the most important in the next 10 years and why?*

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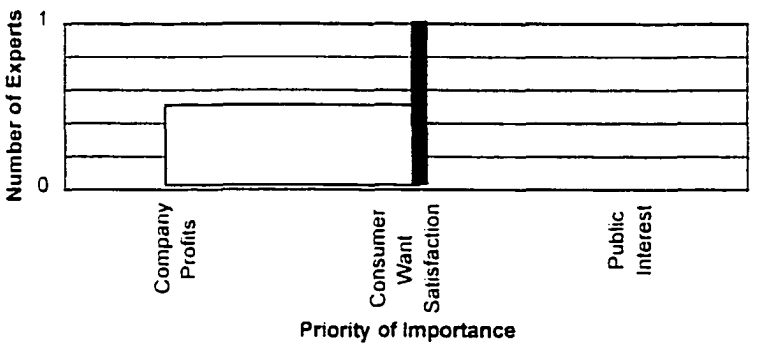
Section II: Question 4



The majority of the experts agreed that consumer want satisfaction was the most important aspect of the choices provided. The second choice of company profits included the basic philosophy that companies need to make a profit to exist. In the consumer want satisfaction, the experts stated that if this was satisfied, then company profits would follow due to continuing and repeat business. The expert that stated public interest as the most important was keying on the changes in a less powerful government and an increase in the information technology which will sway the behavior of companies in the future.

5. *Do you see any effects in the future of Non-Governmental Organizations (NGO's) on environmental management systems, such as the Environmental Defense Fund, Sierra Club, etc.*

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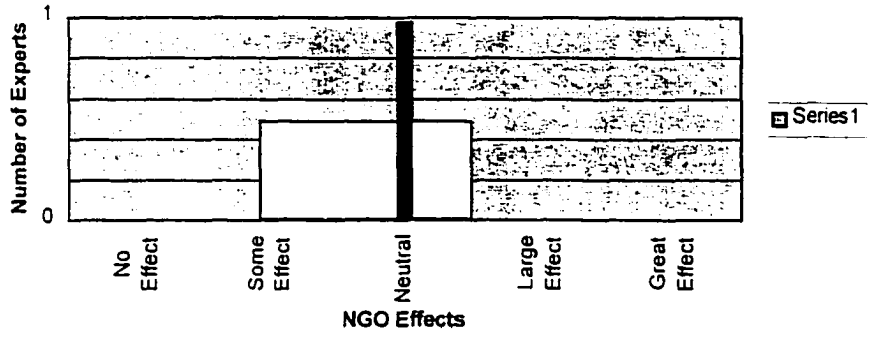
Section II: Question 5



Most of the experts agreed that NGO's will have some effect on the environmental management systems at their companies. This opinion agrees with the literature regarding the affects of NGO's. Most of the literature states that NGO's and the public will sway the behavior of companies in the future.

6. *Do you expect your company, within the next 10 years, to form partnerships with NGO's? For example, the environmental compliance projects between McDonalds and EDF regarding the packaging of their product.*

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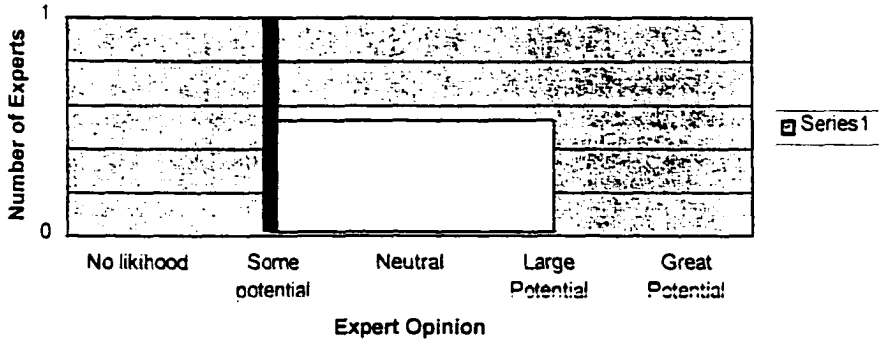
Section II: Question 6



Again, the experts agree that there is some to a large potential for some type of partnership with an NGO. The expert that was neutral stated that there was not a trust relationship at this time, so did not foresee this type of partnership in the future. Some of the other experts stated that the NGO's might also be technical groups that would be helpful in the future, such as a partnership with an ISO organization.

7. *Do you think that your management will be more participatory or future orientated toward environmental matters within the company?*

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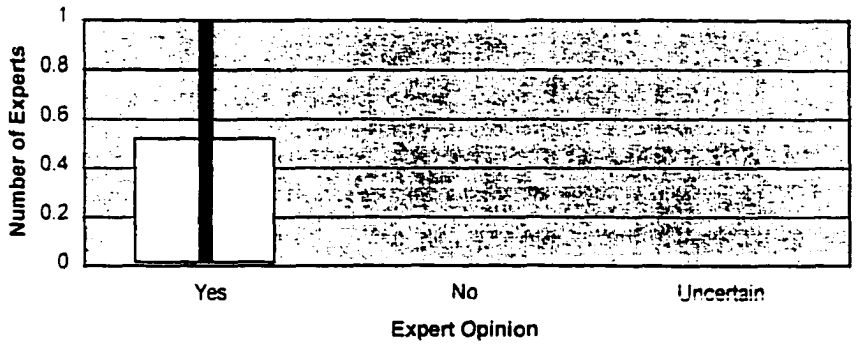
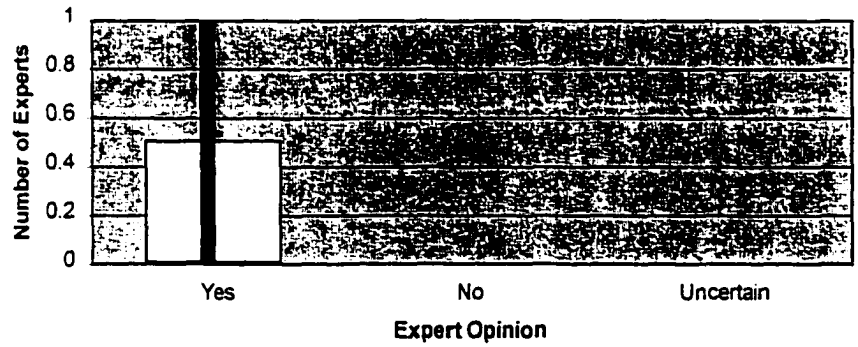
Section II: Question 7



All of the experts agreed that management will be more participatory in the future regarding environmental matters.

8. *Do you believe that your company management, in dealing with outside interests or third parties, will be more participatory or future orientated toward environmental matters outside the company?*

Section II: Question 8



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Again, there was very good agreement by the experts regarding more participation by outside interests. The experts that were uncertain stated that trust was a large portion of this concern.

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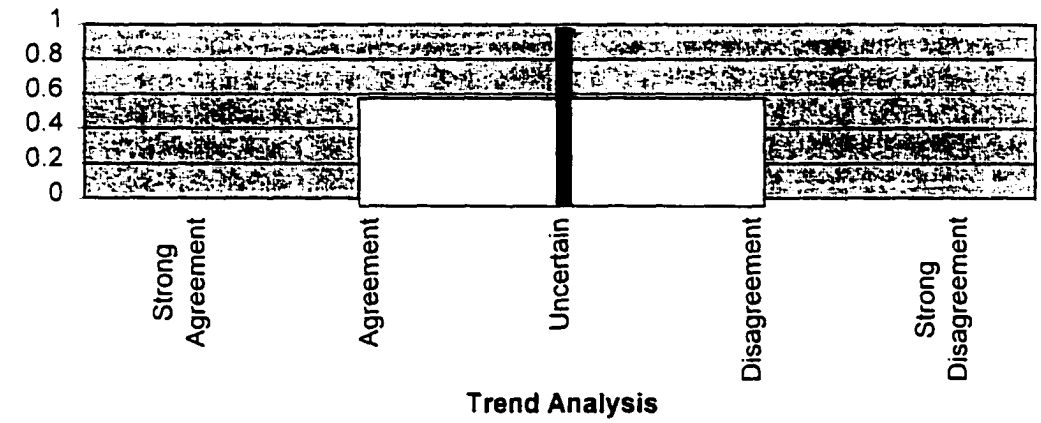
A.4 Part III – Trends for Environmental Management

The following section provides the opinions of the experts regarding future trends for environmental management. The questions were tied to a time frame as to when the experts would anticipate the implementation of this trend.

1. *EMS has been very important in business decisions in the last 10 years.*



The experts were divided among this answer. There was not a future time frame for this question.

2. *EMS will be very important for overall business decisions in the next 20 years.*

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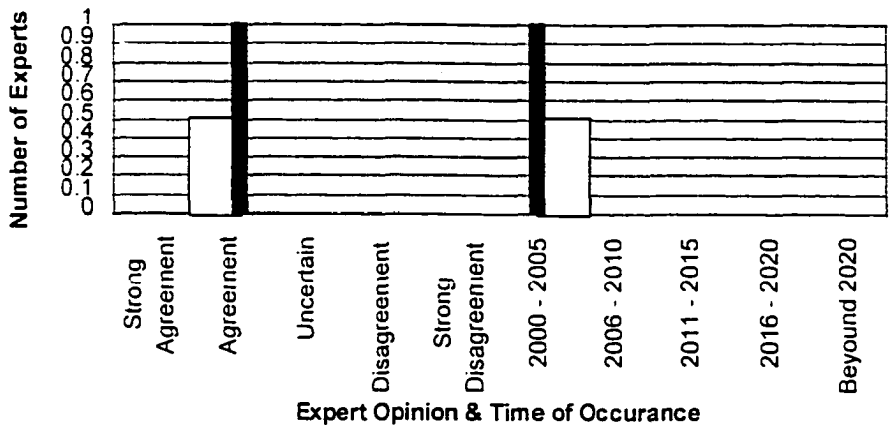
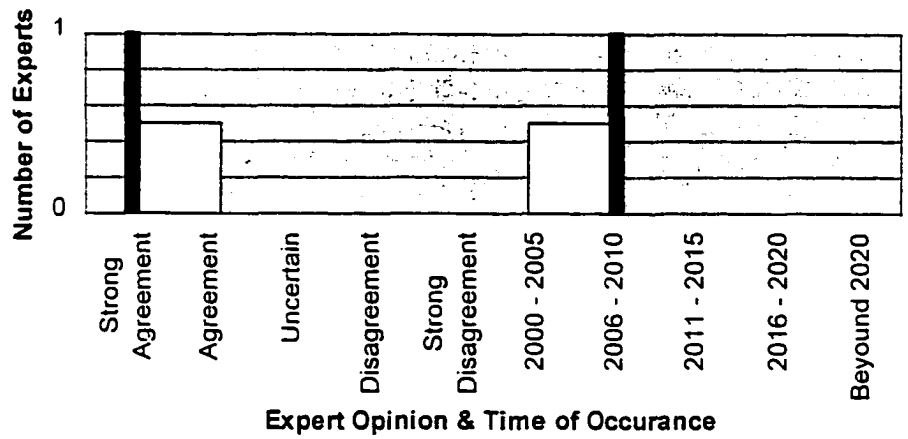


Here the experts were in agreement that EMS will be a very important tool in the future. They also agree that this type of business decision tool will be utilized within the next 10 years.

3. *It is very important for the US EPA to change from a "Command & Control" system of enforcement to a "Co-operative" method of enforcement.*



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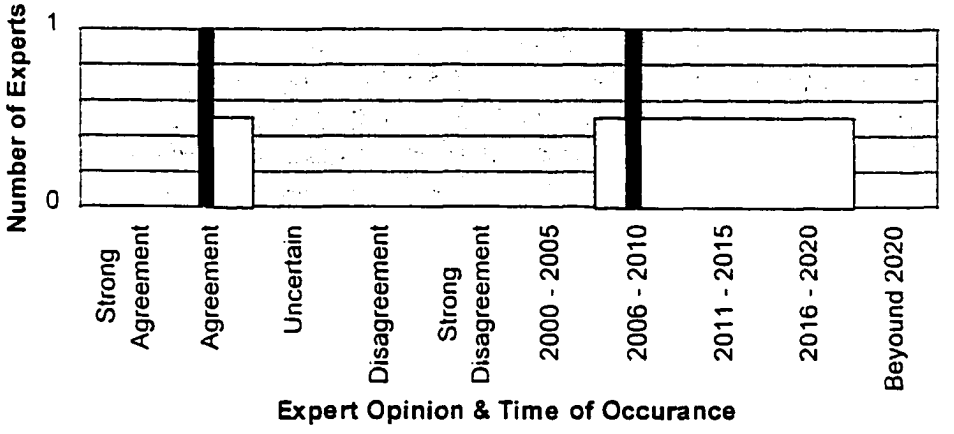
Again, the experts agree that regulatory agencies, such as the EPA will need to move from a "command and control" system of enforcement to a "co-operative" method of enforcement. Most of the experts stated that this should happen within the next 10 years. One expert did not believe this would happen in their lifetime.

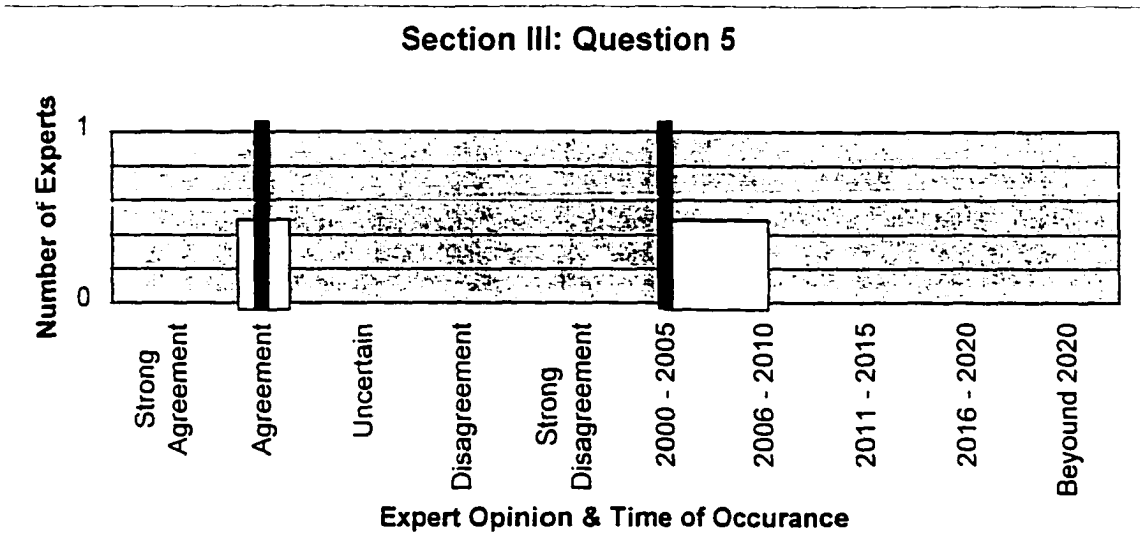
4. *A company should have less EPA oversight for good environmental stewardship and performance?*

Section III: Question 4



Again, there was agreement to a large extent regarding the EPA oversight for good environmental stewardship and performance. A majority of the experts thought this would occur in the next 10 years, while others did not think it would occur at all.

5. *In the future, more public pressure will be applied for environmental compliance.*



Again, there was good agreement that public pressure would be utilized to achieve environmental compliance. Again, this agrees with the literature regarding environmental actions in the future.

6. *With the new trend of rapid information and complex working environments, more dependence will be required on engineering judgment, rather than pure engineering calculations.*

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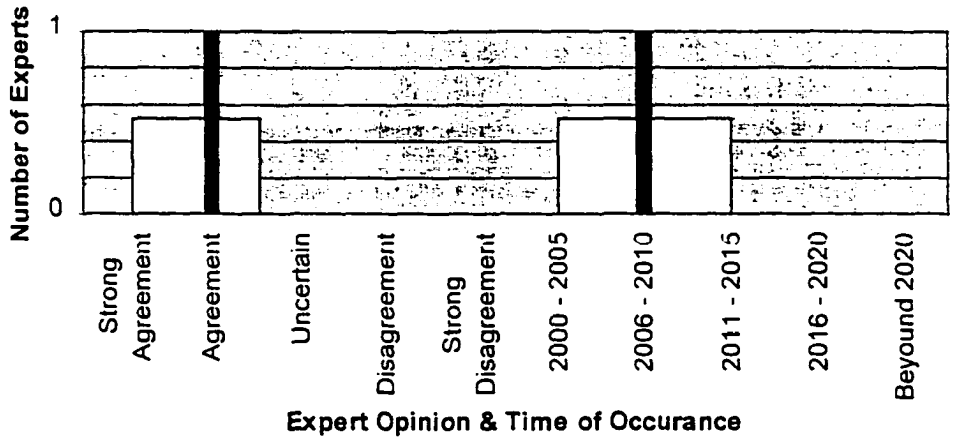
Section III: Question 6



While there is a majority that agrees that engineering judgment will be required in the future, rather than pure engineering calculations, there are those experts who believe that engineering calculations will continue to play a major role in environmental decisions. Most of the experts agree that this change in working philosophy will occur within the next 15 years.

7. *Continuing with the above trend of a complex working environment, shared decision-making (i.e., with other management sectors within the company) will occur more often with regard to environmental matters. An example would include the involvement of marketing department with regard to environmental product labeling.*

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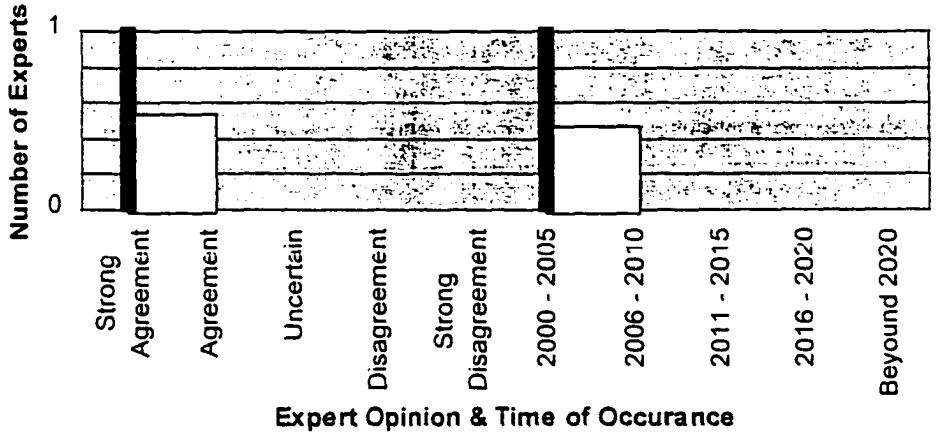
Section III: Question 7



The experts believe that shared decision making will be part of the overall trend for the future. They also believe that this will occur within the next 10 years.

8. *In the future, there will be more uncertainty with regard to implementation of environmental management.*

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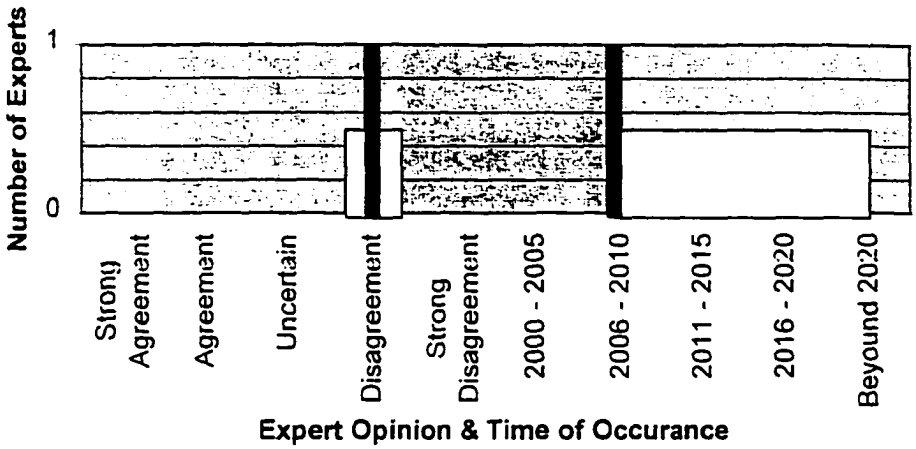
Section III: Question 8



The experts do not believe that there will be more uncertainty in the future with regard to environmental management. They also believe that this will occur within the next 15 years, or beyond the year 2020.

9. *The concept of "reasonable profit" and "corporate environmental stewardship" or "green companies" has become fashionable. Companies will be moving more towards this concept of reasonable profit.*

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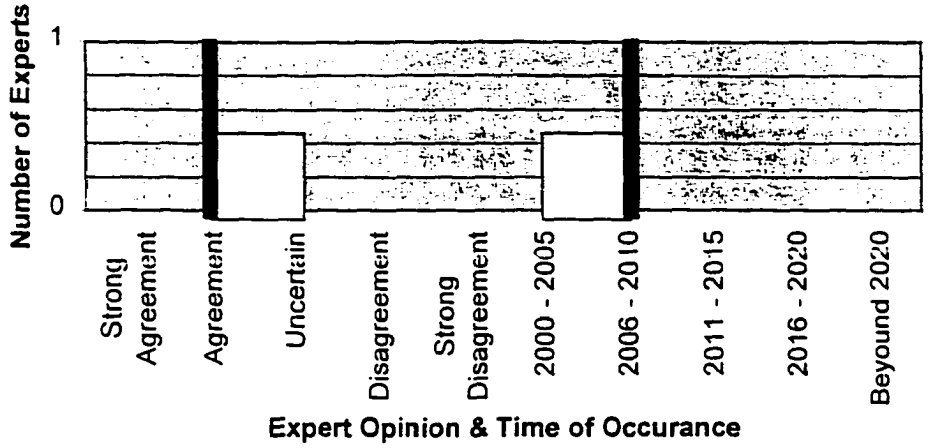
Section III: Question 9



While a majority of the experts agree that companies will move more toward the concept of reasonable profit, there are still companies that do not hold that concept at this time. Most of the experts believe that this change in reasonable profit will occur within the next 10 years.

10. *It is important to incorporate the concept of risk and reward in making decisions regarding environmental management.*

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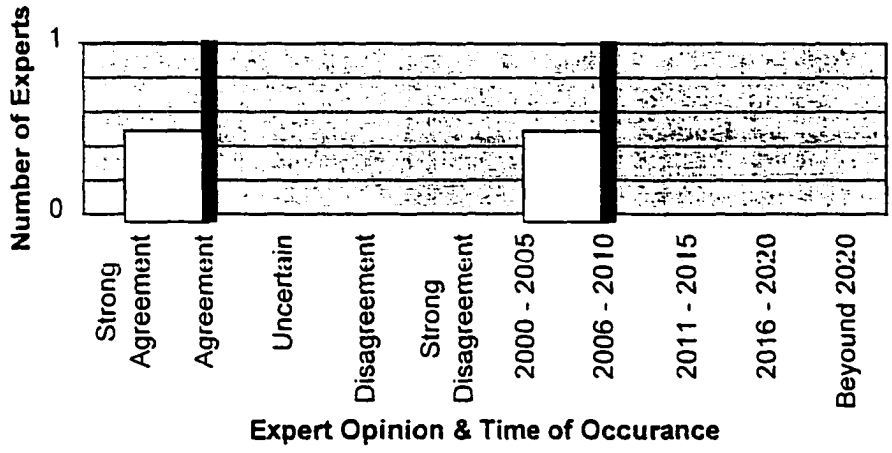
Section III: Question 10



All of the experts agree it is important to include the concept of risk and reward into environmental decision making process. They also believe that this will occur within the next 10 years.

11. *More involvement of the strategic management groups will be required in making decisions regarding the environment.*

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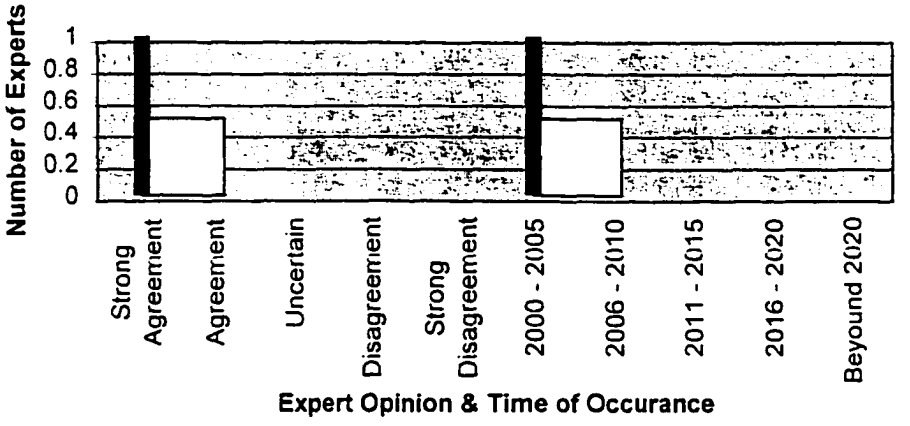
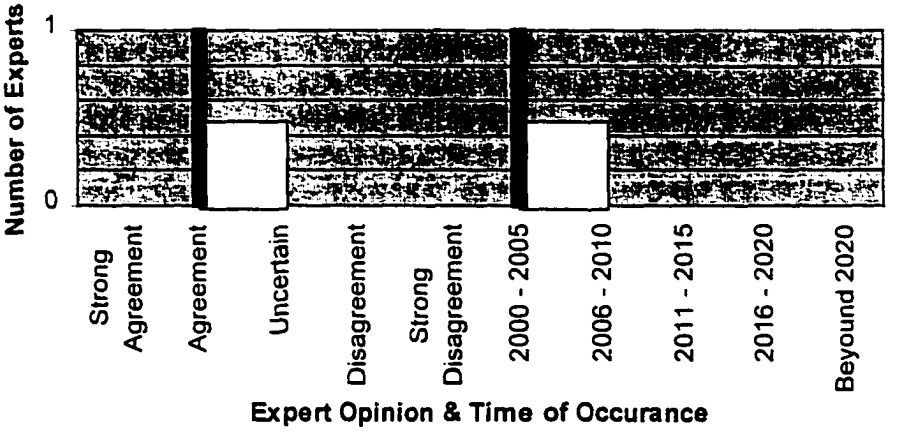
Section III: Question 11



All of the experts believe that more strategic management groups will be required in decision making in the future. They also believe that this type of management will be utilized within the next 10 years.

12. *Company members are demanding more environmental integrity.*

Section III: Question 12



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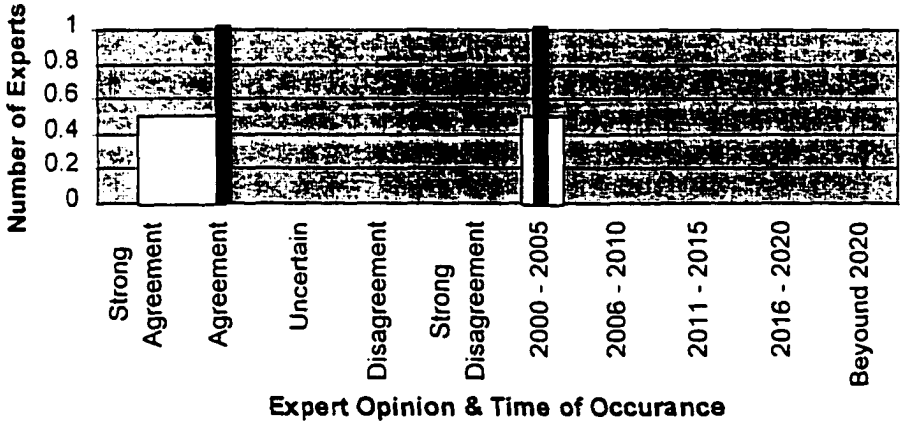
The majority of the experts believe that company members are demanding more environmental integrity. They also believe that this will be more along the norm within the next 10 years.

13. *Younger company members are demanding more environmental sensitivity (e.g., sustainable development).*

Section III: Question 13



Again, there was strong agreement that the newer members or younger generation of company employees were searching for more environmental sensitivity. The experts also agreed that this was going to happen within the next 5 years or a more immediate trend.

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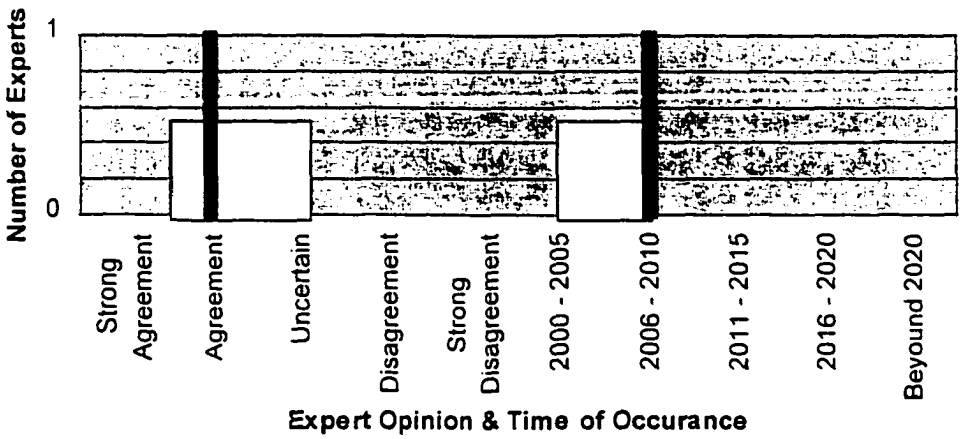
14. *Companies will begin utilizing a separate "Environmental Annual Report", which discusses the companies environmental policies and activities.*

Section III: Question 14



This trend of environmental annual reports had the majority either agreeing or uncertain about their use in the future. However, this trend of environmental annual reports would be implemented in the next 10 years.

15. *Governmental agencies will begin providing tax incentives for companies that provide sustainable development activities for their products.*

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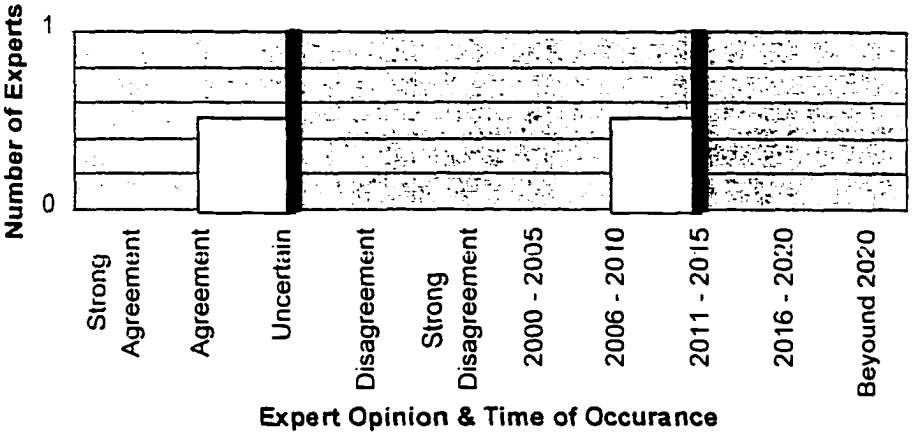
Section III: Question 15



There was good agreement among the experts regarding the government being more proactive regarding tax incentives for sustainable development activities. If the government were to do this, most likely in the next 15 years.

16. *More regulatory changes will occur in the future than has happened in the immediate past.*

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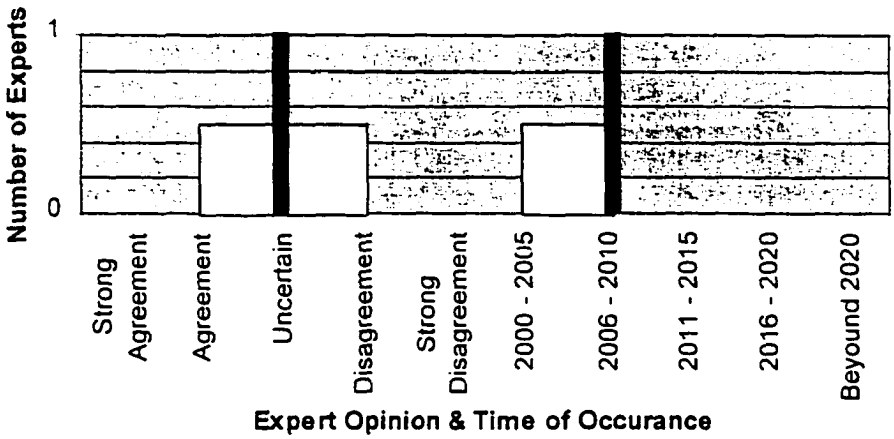
Section III: Question 16



There was not a consensus among the experts regarding more regulatory changes in the future vs. the immediate past. However, any changes that occur will happen within the next 10 years.

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Additional Comments Section

In order to be more complete in the survey, we allowed each expert the opportunity to add comments to the survey. The first part of this "Additional comments" section is as follows:

Are there any factors that you consider crucial to environmental decision making that we have not discussed?

- Do you believe that ISO 14000 registration will be essential to conducting international business in the future?
- Competitive advantage – competition establish proactive position
- Customer focus-willingness to support/pay for environmental improvement or demand them at the same price
- Engineering success – sustainable system e.g. hydrogen as fuel, etc.
- Public understanding – raise knowledge level in science curriculum to better than K-6 mentality
- Outreach programs – there are efforts currently underway to help government and companies to work together without the threat of enforcement. If we are to get anywhere with EMS, then we need to get beyond enforcement. We need to assist all industrial users. Determine if they can be the future and help those who will not be able to comply, transition out without penalty.

Those that are able to move forward must have some type of assistance to further upgrade, to support the increased demand for services. EMS is a team effort that government, companies, NGO's and industry must come together to achieve. All must want to do it. If it becomes pure enforcement, then we all lose.

- Dave, I believe that you have included this but add my note for emphasis: It is crucial to have a policy in regard to environmental matters, a policy written and endorsed by CEO's or down through management ranks; It becomes the common thread, the guiding light for environmental decisions EVEN if it just says to comply.
- No; most crucial are regulatory, public perception; what is environmentally correct, cost, payback period, etc.
- We've focused on a paradigm shift within an organization without addressing an analogous societal shift. If consumers were more motivated by sustainable growth than personal need satisfaction, then these EMS changes would occur more rapidly.
- We need an improved methodology for risk/benefit comparisons. Risks and costs appear to be objective (costs more so than risks), while benefits are often vague or mushy. With this type of "Quantification", hard quantities overwhelm soft quantities.

- Also alienation and its affect on the large developing countries on the environment, e.g. China and India. The emergence of new environmental issues like global warming and endocrine disrupters.
- The use of "politically promoting science" vs. scientifically sound and defensible science in setting policies.
- The degree of influence on environmental policy and enforcement of existing laws that changes in national political parties and agendas brings.

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Is there any thing else that you would like to add to this survey?

- The shift which we are trying to measure and which should occur can and will only occur through strong leadership and rewards. We need to continue to create a sense of urgency, e.g., competitive advantage, corporate integrity, social responsibility, environmental improvement (global warming), etc, to create a need – documented need – to decision makers – to effect change. Unfortunately, most social change is still based on a sense of urgency and/or crisis management!
- We must take EMS not as a stand alone program and tie it into business plans. To do this, some companies will have to increase their work force to hire professionals, an cultural change will have to happen to do this and it will take a strong person to put everything into proper perspective. All concerned stakeholders should have a decision matrix which shows the impact any new regulation has on industry and what the new regulation payback is. Making rules for rules sake is not particle, feasible and definitely not cost effective. If society wants increased costs, then put all the rules you want into effect, the loser is the consumer.
- I believe that major and larger companies will incorporate EMS into their way of doing business – including continuous improvement.
- Smaller independent companies will continue to struggle with environmental needs and requirements and not have much focus on environmental

performance improvement. Perhaps this is the consultant niche – helping small companies become leaders.

- It is very important to have upper management on board with the EMS. If you do not, you are always fighting uphill. You can implement the system, but it will not get allowed through unless upper management is also convinced and on board.
- Make it (the survey) available electronically. I've almost forgotten how to use a dictionary for spell check and my hand writings lousy.