Integrating Environmental Responsibility into Decision Making in the Manufacture of Non-Standard Discrete Products

by

William N. Anderson

B. S., Chemical Engineering
University of Texas, 1988

Submitted to the Sloan School of Management and the Department of Chemical Engineering in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Management
and
Master of Science in Chemical Engineering
at the
Massachusetts Institute of Technology
June 1995

Signature of Author ______________________________

Certified by ______________________________
Henry D. Jacoby
William F. Pounds Professor of Management
Sloan School of Management
Thesis Advisor

Certified by ______________________________
Gregory J. McRae
Joseph R. Mares Professor of Chemical Engineering
Department of Chemical Engineering
Thesis Advisor

Accepted by ______________________________
Jeffrey A. Barks, Associate Dean,
Sloan Master's and Bachelor's Programs

Integrating Environmental Responsibility into Decision Making in the Manufacture of Non-Standard Discrete Products

by

William N. Anderson

Submitted to the Sloan School of Management and the Department of Chemical Engineering in Partial Fulfillment of the Requirements for the Degrees of Master of Science in Management and Master of Science in Chemical Engineering.

ABSTRACT

Over the course of the past twenty years environmental concerns have become increasingly important to corporations in America and around the world. Environmental activists, governments, and individuals have exerted pressure on manufacturing firms to reduce and eliminate the wastes that enter the environment as a result of production, use, and disposal of their products. In response to these pressures, many manufacturing firms have initiated programs that seek to "take the lead" in pollution prevention rather than waiting for government regulations or environmental activist campaigns to force their hands.

United Technologies Corporation, for one, has written "Standard Practice" guidelines dealing with minimum expectations for manufacturing plants. However, these documents mention corporate responsibility and sensitivity to environmental concerns, but offer little direct guidance to the management of individual plants. At the plant level there are many barriers to implementation of an effective environmental policy. These barriers include a lack of baseline data about what the amounts and sources of pollution and waste are, a deficiency in understanding of how pollutants and waste from operations affect the workers and members of the community, and a paucity of clear incentives for environmental improvements. A plant such as Otis Elevator's Bloomington, Indiana site presents an additional challenge in analysis of environmental performance due to the fact that a large variety of non-standard products are manufactured, each with different potential waste contributions.

This research examines the challenge of integrating environmental concerns into the decision making process at non-standard discrete manufacturing facilities and describes the progress made in this endeavor in two complimentary areas:

- Chemical Tracking - A starting point for lessening a plant's impact on the environment is providing a snapshot the of the plant's emissions. In many cases, individual facilities

lack the resources to provide such an analysis, and thus often an external consultant is brought in to perform an emissions study. However, although a snapshot may be a good first step, a more dynamic picture is necessary to allow for good decision making on an ongoing basis. A major part of this study will encompass the provision of chemical tracking systems to provide timely information about the impact of plant operations on the environment.

- Financial Incentives - In a capitalist economic system, the primary drivers for business decisions are financial. Thus, it is necessary to devise timely and accurate methods to determine the financial implications of environmental-based product or process changes. Here, various options for including the values of environmental changes in cost-benefit analysis are examined. Also, recommendations are made for improving the prevalent methods of plant cost accounting to include environmental costs of products and processes.

Several themes which are discussed throughout the study include the need for top management support in improving environmental management, the resistance to change shown by many areas of the manufacturing organization, and the conflict between environmental*ism* and sound scientific decision making.

Thesis Supervisors: Henry D. Jacoby, Sloan School of Management
Gregory J. McRae, Department of Chemical Engineering

Acknowledgments:

The author would like to recognize the moral and financial support and time given by a number of United Technologies employees. Larry Bryan, the EH&S manager at the Bloomington site made the largest contribution in terms of pure time and effort. Jerry Kent, the operations manager at Bloomington, and the rest of the Otis team were instrumental in providing input for the lessons learned in this study. Lisa Szewczul, the EH&S vice-president for Otis, provided the funding which allowed the internship to happen. At the United Technologies Research Center, Jerry Golden and Mark Jaworowski contributed greatly, both with technical resources as well as with logistical and moral support.

The author wishes to acknowledge the Leaders for Manufacturing Program for its support of this work.

Finally I'd like to thank my advisors, Greg McRae in Chemical Engineering and Henry Jacoby at the Sloan School of Management for their timely advice and their desire to learn with me as they work towards integrating environmental management into the business of manufacturing.

Bill Anderson
Cambridge
May 1995

Integrating Environmental Responsibility into Decision Making in the Manufacture of Non-Standard Discrete Products

Part II. Incenting Environmental Improvement at the Plant Level

1. Introduction

1.1. Preliminaries

This thesis is the result of six months of work sponsored by United Technologies Corporation and the Leaders for Manufacturing Program at M.I.T. The United Technologies Research Center was the internal sponsor of the project with the Otis Elevator Plant in Bloomington, Indiana serving as the principle site. This section first describes the purpose of the thesis and the problems which are examined. It goes on to provide a road map for the organization of the thesis and lists the main contributions of the thesis.

The purpose of this thesis is to examine environmental management at the plant level in discrete manufacturing and specifically to work towards the integration of environmental management into the business of manufacturing. The problem which it attempts to address is the lack of synergy between plant environmental management and the general management of a plant. Companies spend a lot of time and money on environmental management in general, but implementation is often ineffective, especially at the plant level. Some of the symptoms which point to a lack of connectedness between environmental management and the business include:

- a plant's environmental strategy is often very short-term oriented,
- plant managers are interested in environmental management only on a crisis basis,
- environmental data is often inaccurate or incomplete,
- methods of managing environmental data are often very inefficient (redundancy, etc.),
- environmental management is often a "dead-end" job.

Greater integration of environmental management into the business of manufacturing should help to eliminate these types of problems by tying environmental issues into the tactical and strategic decision making processes. This thesis examines two areas which should foster good environmental management at the plant level. The first area is that of access to environmental data which is required by numerous federal, state and local laws and regulations. Data access must be improved in terms of timeliness, accuracy, and efficiency to provide managers with quality bases for decision making at the lowest possible cost. The second area considered is that of Total Cost Assessment for products and processes - to bring out all relevant costs including many hidden environmental costs which might be overlooked by standard cost accounting methods. Total Cost Assessment should help to integrate environmental decisions into general management by translating them into the language of business: money. The factors driving implementation in both of these areas are considered briefly in the next chapter. The "Conclusions" chapter discusses the forces supporting and opposing their implementation.

For the most part, the problems encountered were neither strictly technical nor strictly organizational. In each section I will attempt to outline both the technical and the organizational side of the issue. In addition, there were some organizational factors which affected a number of the individual issues dealt with. These overarching organizational factors will be discussed in the Chapter 6. In order to facilitate an understanding of the relationships between the areas of study, a "road map" of the thesis is provided in Figure 1.1.

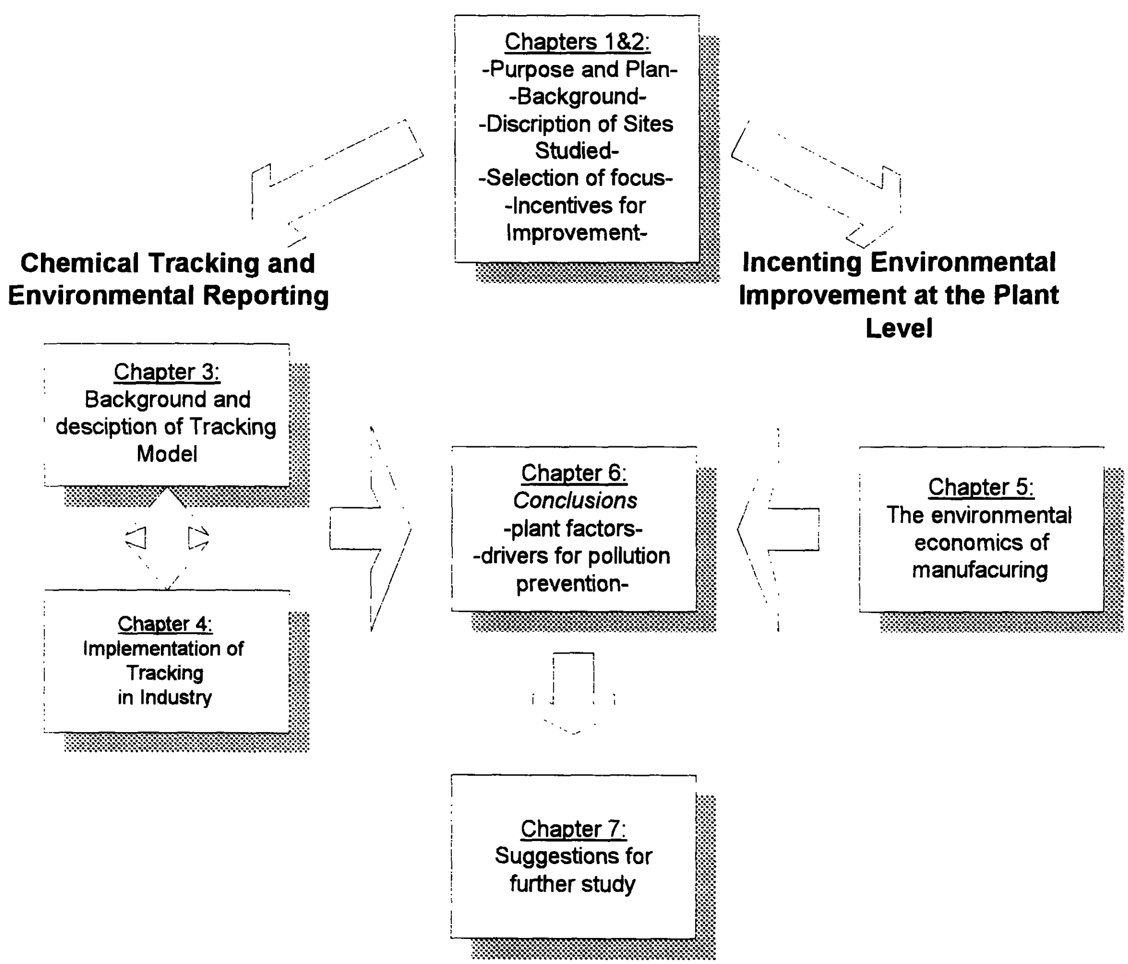

Figure 1.1 Road map of the thesis organization

I believe this thesis provides contributions in three areas:

1. It presents a model for accurately and efficiently tracking chemical usage and emissions and gives guidance for successful implementation of such a model at a manufacturing plant.

2. It provides a tutorial on manufacturing cost accounting systems and effective use of these systems for economic justification of pollution prevention projects. A case study is presented to highlight the use of a Total Cost Assessment methodology as well to demonstrate the estimation of intangible costs such as future liabilities for hazardous waste disposal.

3. It traces the factors which determine the success or failure of implementation of chemical tracking and Total Cost Assessment and provides guidance for a manager embarking on these routes.

1.2. A new focus for environmental management

There are many topics within the environmental realm which are receiving or have received extensive coverage in academic and industry journals. Among these topics are Design for Environment (DFE), Product Life Cycle Assessment, Total Environmental Quality Management, and Total Environmental Cost Analysis. Due to a combination of public pressure and government regulations, most companies have a strong motivation for pursuing these and other topics which promise to improve environmental performance. At United Technologies Corporation for example, projects in DFE and life-cycle analysis have been undertaken over the past several years, in hope of lessening the upstream and downstream effects of products and processes on the environment. Projects in waste elimination, source reduction and elimination of ozone depleting compounds have been hotly pursued for a decade. As a result of these efforts, many of the worst polluting processes have been eliminated or substantially modified.

A quick review of other corporations' environmental reports indicates that the environmentally-based activities of United Technologies in the recent past are typical of those of large manufacturing corporations across America. However, while companies have ongoing efforts in research and development, marketing, and corporate environmental offices to search out and implement green processes and products, there has been less attention focused on helping manufacturing sites effectively cope with environmental management and improvement in their day to day operations. It has thus been my goal in this thesis to profile areas of concern in daily environmental management at the plant level. More specifically I will focus on operations at plants producing discrete items. This topic is interesting both because the plant level has been somewhat neglected in past academic studies, and because the production of discrete items offers special challenges in environmental management.

1.3. *Plant level environmental management in discrete manufacturing*

What are the environmental concerns faced by manufacturing sites producing discrete parts? Since historically it has been the oil and chemical industries and electric utilities which have received the most public scrutiny concerning operations and the environment, one might suppose that there really isn't much of an environmental issue in the manufacture of items such as automobiles or elevators. In fact, the manufacture of discrete items often involves a number of processes which have serious environmental impacts. Such processes include surface treatment and coating, adhesive bonding, galvanization, resin impregnation, and chemical etching, to name a few. Consider an example: A chemical plant might produce 100,000 tons per year of toluene and release 100 tons per year to the air, but if a discrete products plant purchases 100 tons of toluene contained in a paint, most likely it will also release 100 tons per year to the atmosphere. The solvent is a valuable product to the solvent producer, but it is a "disposable" carrier to the painting operation. When considered over a geographical region with a number of manufacturing sites, discrete manufacturers can be large contributors to a pollution problem.

Environmental management at the discrete product plant includes a number of areas of responsibility. Among the duties of the environmental management professional are permitting and compliance with federal, state, and local environmental regulations, disposal of hazardous and non-hazardous wastes, initiation of pollution prevention and pollution abatement projects, and various stewardship tasks such as making sure that chemicals and processes employed do not result in unsafe exposures to employees.

All too often, and for a number of reasons which will be more fully described later, the responsibility for environmental stewardship falls solely on the environmental professionals at these plants. This is a highly unsatisfactory situation because a lone environmental engineer can hardly be expected to monitor the decisions and actions of the 200 to 2000 employees at a typical plant. Thus there is a real need for integration of environmental responsibility: integration across all plant personnel *and* integration across the range of decisions, both daily and strategic, at the manufacturing site.

Since environmental issues are not primary concerns at many discrete manufacturing facilities, the person responsible for environmental affairs is often expected to coordinate other functions such as safety, medical, and industrial hygiene as well. Sometimes these duties might even include facilities management and security as was the case at Otis Bloomington. This need for the environmental manager to wear several hats may also set apart many discrete manufacturers from their process counterparts who have tended to set up environmental groups which focus solely on environmental management. As a result, the actual *environmental* staffing at a discrete products plant is often only a fraction of one person. This low level of environmental staffing has a significant impact on the proper design of systems and structures for environmental management at a discrete products plant.

1.4. ***Overview of operations at Facilities Studied***

The facilities examined for this thesis consisted of manufacturing operations at a number of the United Technologies companies including Hamilton Standard in Windsor Locks, Connecticut, a producer of propellers and specialty components primarily for defense applications, Sikorsky Aircraft in Stratford, Connecticut, the producer of a range of defense and commercial aircraft, Carrier in Indianapolis, Indiana, a producer of residential heating, ventilation, and air conditioning systems, and United Technologies Automotive in Edinburgh, Indiana, a producer of a range of molded parts for the automotive and electrical appliance industries. In addition, a film production and packaging facility of Polaroid in Waltham, Massachusetts was visited and environmental professionals from a number of discrete and process industries were consulted.

The primary base for study was the manufacturing site of United Technologies Otis Elevator in Bloomington, Indiana. This site is the sole production site for Otis in the United States, and it produces elevators which are installed in both U.S. and export markets.

The Bloomington plant produces two broad categories of elevators: traction elevators, which are suspended and lifted by a cable attached to an above-mounted motor, and hydraulic elevators, which are mounted on a "piston" which is raised and lowered by hydraulic pressure. Beyond these two broad categories, there are two main types of traction elevators denoted by the type of mechanism used to lift the elevator and there are a variety of sizes and styles of elevators which are offered.

At this point some background on the Otis product philosophy is needed to provide a proper perspective on the types of challenges involved in environmental management at the plant level. Otis has a strong identity as the "we can build anything" elevator company. The Otis Bloomington site epitomizes this ideal with production of such specialty items as the "Tower of Terror" giant falling elevator for Disney, the diagonal lift elevator for the pyramid shaped Las Vegas Luxor Hotel, and elevators for the world's tallest buildings including the World Trade Center in New York and the new Kuala Lumpur City Center in Malaysia.

Between the long list of "standard" models and the frequent custom and exotic jobs, a wide variety of elevators are produced in Bloomington. All elevators must meet the specifications of individual customers and it is fair to say that no two jobs are exactly the same. Further, the Bloomington facility has a high degree of vertical integration; sheet steel is cut, worked, joined and painted to make doors and entrances, long steel pipes and beams are milled and straightened to make pistons and rails, and large blocks of steel are cut and milled and then hand wound and varnished to make the large motors which power the elevators. Electronic control panels are hand assembled on-site in clean rooms, and many specialty electrical items related to power supplies are fabricated on site. Trim for elevators is handmade from materials such as brass, stainless steel, plastic, glass, and hardwoods. In short, the manufacturing operation at Otis Bloomington is characterized by a high degree of complexity involving diverse processes and materials. It would not be unfair to say that the plant has to deal with a product as intricate as a mass-produced automobile, but with level of customization more comparable to a construction project.

From the background on environmental management in discrete manufacturing provided in this chapter, the reader should have an idea of some of the challenges faced by plants in improving their environmental performance. The next chapter provides a development of the two areas emphasized in this study: chemical tracking and the use of economic evaluation and incentives for environmental improvement.

2. Drivers for Pollution Prevention at the Plant Level

Two general areas will be briefly introduced in this chapter concerning the factors which contribute to pollution prevention at a plant. First, the features of a successful pollution prevention program are described using a framework developed in previous work. Two of these features in particular, chemical tracking and Total Cost Assessment (also known as *Total Environmental Cost Accounting* or *full cost accounting*) form the main thrust of the rest of this thesis. Secondly, several external forces which can motivate environmental improvements are discussed briefly, since these forces are important for determining the extent of commitment which the environmental effort receives from plant and corporate management.

The pollution prevention program features and the external motivating drivers for improvement are introduced in this chapter to provide a backdrop for the chemical tracking and Total Cost Assessment parts of the thesis. A more rigorous discussion of these factors as well as their interaction with the chemical tracking and Total Cost Assessment implementations will be provided in the conclusions in Chapter 6.

2.1. Components of a successful P2 program

One organization which has extensively studied the factors which contribute to a successful pollution prevention effort at the plant level is the group INFORM. In a 1992 study published by INFORM (Dorfman, et.al., 1992) pollution prevention progress at 29 different manufacturing sites, primarily in the chemical industry, was examined. The report presented the plants' source reduction accomplishments, program features, motivation for improvement, and techniques used. Based on results from the 29 sites, eight environmental program features were evaluated on their ability to promote improvement. These eight features are listed and described in Table 2.1.

Of the eight program features examined, only three showed a significant correlation with the amount of source reduction progress. These features were cost accounting, employee involvement, and leadership. Of these three, the research reported here focused on the first, cost accounting. In the INFORM study it was noted that in order to implement a full cost accounting system, a materials accounting system must already be in place. This would tend to support the main premise of this thesis: that the combination of materials accounting and full cost accounting is a significant contributor to a pollution prevention effort. The relationship here is portrayed in Figure 2.1.

Program Feature	Description
Written source reduction policy	A policy that promotes the primacy of source reduction as a waste management strategy in any explicit, written statement.
Leadership	Management-level responsibility for ensuring source reduction progress.
Materials accounting	A tracking of the inputs and outputs of the various individual chemicals consumed, generated, or processed in a plant.
Materials balance	Quantitative assessment of chemical inputs and outputs of individual processes to determine if all sources of waste have been identified.
Full cost accounting	Accounting procedures that incorporate pollution costs into the plant's cost accounting system and assign the costs to individual products and processes.
Employee involvement	Programs to involve employees at all levels in the companies source reduction activities.
Environmental goals	Specific goals set for reduction of the generation or release of specific chemicals and waste streams.
Environmental program	A formal program dedicated to environmental issues in general.

Table 2.1 Environmental program features evaluated by 1992 INFORM study

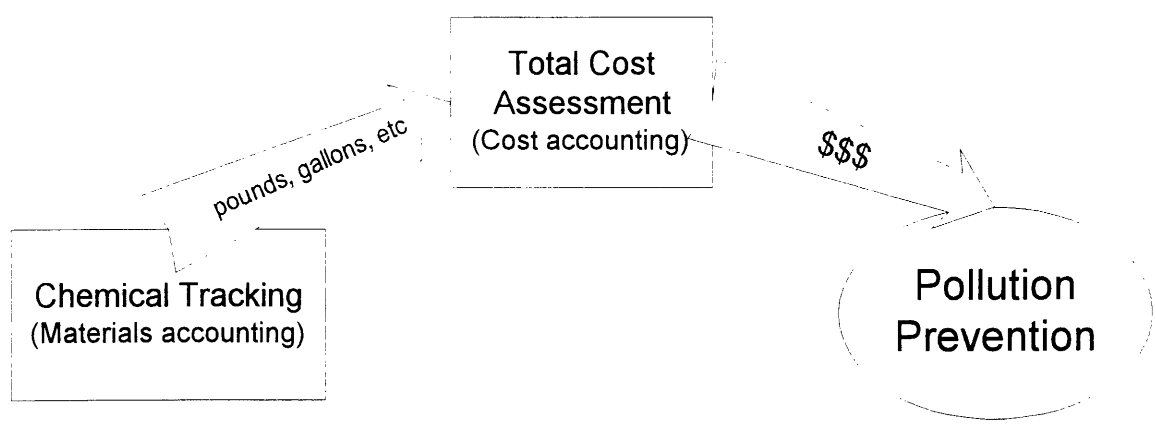

Figure 2.1 Drivers for pollution prevention

In this relationship a chemical tracking system first serves to provide data on the flow of chemicals in and out of the manufacturing process, and the Total Cost Assessment system converts these flows into money. Hence the chemical tracking system is the source of the raw data and the Total Cost Assessment based accounting system is the key which converts this raw data into meaningful economic terms.

A number of the other features listed in Table 2.1, including leadership and employee involvement, have an impact on the implementation of chemical tracking and Total Cost Assessment at a given site. In addition, during the course of the work at United Technologies other factors were observed which appeared to have a strong influence on the effectiveness of a pollution prevention program. These types of concerns are addressed at length in the conclusions in Chapter 6.

2.2. External drivers for pollution prevention

In addition to the features which make up a plant's environmental effort, there are a number of "external" forces which can create strong incentives for environmental improvement. Such forces include government regulations, community pressure, and the desire to maintain a good public image. INFORM's report (Dorfman, et.al., 1992) also listed the results of a survey conducted for 162 different source reduction projects to determine the motivating factors for each. The categories of motivating factors which they considered were: waste disposal costs, environmental regulations, product output, liability, and "other". A recap of their results is found in Table 2.2. In addition, since the same group conducted a similar survey in 1985, the authors were able to determine the increase in these various types of projects over this seven year period. The "% Change" column in Figure 2.2 lists the percentage increase in number of source reduction projects at the survey facilities according to the motivating factor.

Motivating Factor	Total No. of Activities	% Change (1985-92)
Waste disposal costs	67	+119 %
Environmental regulations	58	+300 %
Product output (yield, customer spec., operating costs, etc.)	43	+111 %
Liability (worker safety and community relations, as well as future liability)	32	+50 %
Other	26	+17 %

Table 2.2 INFORM data on motivation for environmental improvement

By examining these motivations for source reduction, one can further see the importance of chemical tracking and Total Cost Assessment to the pollution prevention effort. For instance, Total Cost Assessment provides a way to flesh out the economic significance of three of these categories: 1) waste disposal costs, which must be properly allocated to processes and products, 2) product output costs, which can be quantified by accurate accounting, and 3) liability costs, some of which can be estimated using techniques described in this thesis. Further, a good chemical tracking system provides a way for a plant to ensure compliance with environmental regulations. In this sense, the chemical tracking data becomes a direct input to pollution prevention. This added relationship is shown in Figure 2.2:

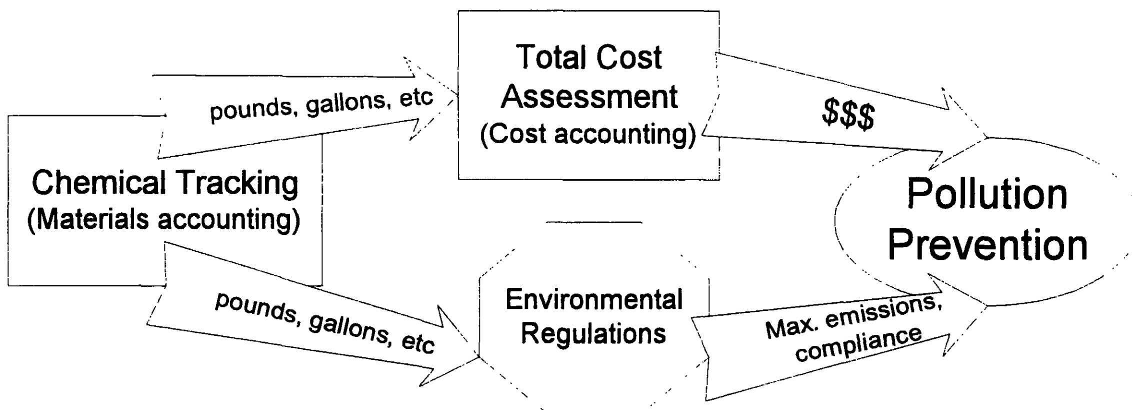

Figure 2.2.2. Drivers for pollution prevention including environmental regulations

The next chapter begins the main body of the thesis; the subject of external drivers for pollution prevention will be further developed in the conclusions in Chapter 7.

Part I : Chemical Tracking and Emissions Reporting

Almost every technique or tool available for approaching environmental improvements makes one basic assumption: the current environmental impact of a process is known. However, this assumption is not necessarily valid for many manufacturing sites. Over the past decade the practice of taking an environmental "inventory" has become widespread and most plants have at least taken a one-time snapshot of their environmental impacts. However, especially in a plant which produces a large number of non-standard products, this snapshot view is only useful for a short time after completion.

Consider a typical discrete manufacturing plant where 200 to 1000 different chemical products are in use at any one time with a product turn-over of 50 to 100 products per year. Without a systematic method for tracking the use and emissions of these various products, the environmental professionals at that facility will face a difficult task in even trying to understand the sources of pollution. In some of the plants surveyed for this study, environmental management is the responsibility of one or two persons who may have considerable duties outside of environmental management. In this context, the environmental manager must content himself with scrambling to complete permit applications and government mandated forms. Hope of using this data for tackling the sources of pollution, except for the most blatant ones, must be relegated to tomorrow's "do-list"

In addition to the fact that an increasing amount of environmental data is required by governmental mandate (this is more fully described in Chapter 3), the availability of timely data on the use and emissions of chemicals is key to empowering the plant environmental engineer to go beyond compliance reporting to proactive environmental impact reduction. Even though the model for providing environmental data presented here is discussed primarily in relation to its ability to handle external reporting requirements, a key benefit of such a model is its ability to both better inform and free-up the environmental engineer for pollution prevention.

Part 1 of this thesis describes the implementation of a chemical and emissions tracking system for use at facilities manufacturing discrete products. Part 1 is divided into two chapters. Chapter 3 presents the purpose and scope of the chemical tracking system considered and gives an overview of the proposed system. Chapter 4 describes the steps necessary for a successful implementation of such a system and describes the follow-up process for maintain it and keeping it up to date.

3. Presentation of a Chemical Tracking & Emissions Reporting Model

Here a model for chemical tracking and emissions reporting is presented which should be generally applicable at discrete manufacturing facilities. The discussion begins with some background on tracking and reporting and a description of the potential role of information systems as tracking and reporting tools, followed by three basic requirements of such systems. The chemical tracking and emissions reporting model which was developed at United Technologies Otis Elevator is then presented, along with explanations of its various components. The implementation of such a model will be addressed in Chapter 4.

3.1. *Background on environmental reporting in manufacturing*

Probably the most significant trend in environmental reporting in manufacturing over the last decade has been the huge increase in government requirements. Since January of 1993 alone, more than 300 new regulations with reporting requirements have been enacted the federal level. (Rich, 1994) During this same period, state, city, and local governments across the country have been passing new laws and codes which require manufacturers to account for the environmental impacts of their operations. In fact, the proliferation of reporting requirements is a phenomenon which has been taking place for more than a decade. However, more recently the reporting requirements placed on manufacturers have included a much greater level of detail than in the past.

Prior to 1986, an established manufacturing site such as Otis Bloomington would have had a relatively small amount of environmental data to collect. Statistics such as the total volume of hazardous waste generated or an estimate of the total weight of volatile organic compound (VOC) emissions would be provided to the state environmental department on a yearly basis. In 1986, the federal *Superfund Amendments and Re authorization Act* (SARA) changed the nature of environmental data management for manufacturers (Esry, 1993). Under a group of provisions known as *Right to Know* legislation, SARA required manufacturing sites to provide information yearly on inventories, air emissions, releases to land and water, and wastes handled off-site, for a list of about 200 "toxic chemicals". The completion of one of these SARA reports in 1994 for Otis Bloomington took over two man-months.

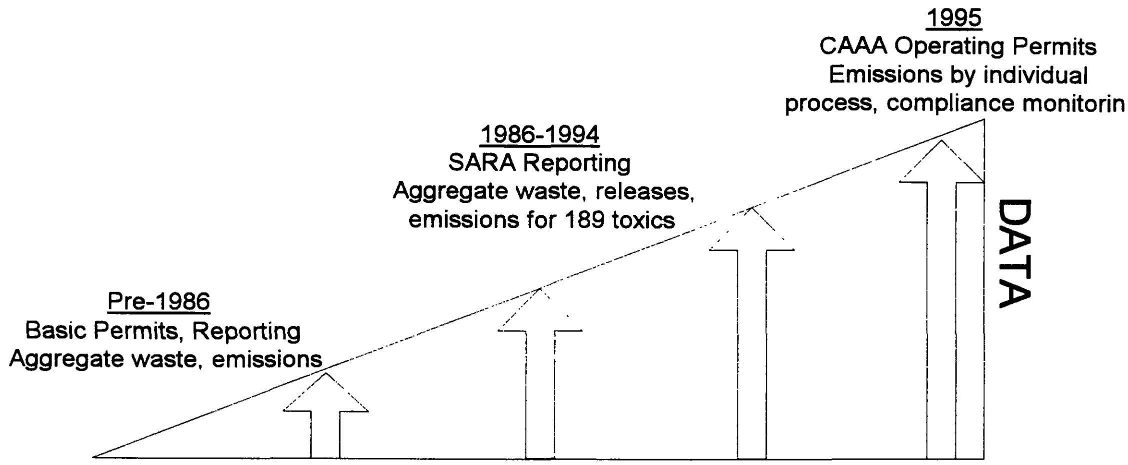

Figure 3.1 Representation of growth in volume of environmental reporting data

This year industry is again faced with a major new demand for environmental data in the form of the *Clean Air Act Amendments of 1990* (CAAA '90). One part of this legislation, the *Title V - Operating Permit* section, requires all facilities classified as "major sources" to obtain operating permits from their state environmental authority for each individual process which has the potential to create a significant environmental impact.* This legislation comes on top of the SARA requirements and other existing regulations. CAAA '90 will have a considerable impact on the complexity of environmental data at the plant level for several reasons:

1. Title V requires a permit covering *all* significant processes at a site - prior to 1995, many processes were exempted from permit requirements by grandfather clauses in state permit laws.

2. Title V requires emissions calculations for *individual processes* within a site instead of the plant aggregate totals required by SARA.

3. Whereas SARA reporting takes place one time per year, Title V requires manufacturing sites to be able to demonstrate their compliance with the operating permit on a continuous basis.

---

* It has not been this author's intent to prepare a complete summary of these various articles of legislation. The interested reader should refer to the actual laws for more complete descriptions of eligibility for permits, threshold values, etc.

The increased reporting requirements of the Clean Air Act Amendments of 1990 will affect an estimated 35,000 industrial plants and will increase the data management task by an order of magnitude. (Sheridan, 1994)

3.2. *Systems solutions to reporting needs*

As would be expected from a situation involving the manipulation of thousands of pieces of data each year, the environmental reporting task has had a lot of attention from systems and software developers during the past ten years. The industry journal Pollution Engineering estimates that it has reviewed 1200 to 1500 software programs for tracking and reporting of chemicals since 1985. (Rich, 1994)

Despite the attention given environmental reporting by software developers and environmental consulting firms, there have been a number of factors which have kept a "final" software solution at bay. Most of the canned software packages are written with only a few (and often only one) specific regulations in mind. Because of this, a given package might report aggregate releases of the 189 air toxics defined by the SARA legislation, but not be able to provide the releases of all VOCs for a specific process within a site - information required under Title V. Also, many software packages tend to focus on producing a "form" which is ready to send to an enforcement agency, but may not provide much help in calculating the values to insert in the form.

At the plants studied for this thesis, a variety of chemical and emissions tracking methods were seen ranging from all-paper calculations to spreadsheets to elaborate database systems. All of these systems were found to be manpower intensive; they also required substantial modification on a regular basis in order to keep up with the latest regulations. One of the plants, Hamilton Standard's Windsor Locks, Connecticut facility was in the midst of installing a solution which they hope will be more permanent in nature. However the high cost of this solution might tend to limit its general use.*

---

* The Hamilton Standard system involves stand-alone environmental logging terminals throughout the plant as well a number of dedicated distribution points and waste receptacles equipped with scales and bar-code readers. A large environmental staff is employed to help ensure the accuracy of environmental data. The management at this facility is keenly sensitive to the need to have accurate reporting after

3.3. *Basic requirements of a chemical and emissions tracking solution*

In order to work towards a system for chemical and emissions tracking which will improve the quality of the environmental information which managers can use to target pollution prevention efforts, and provide timely and accurate information for regulatory compliance, it is useful to define the fundamental requirements of such a system. Drawing from the regulatory dynamics which have been described in the previous section as well as the experience of the different manufacturing sites which I have studied, I have defined three main requirements for a lasting systems solution in chemical and emissions tracking. An eventual system must be robust: able to provide general data which can be manipulated to satisfy changing regulations. It should be simple: able to be used and maintained by professionals who are not necessarily environmental engineers nor computer experts. Finally the system should draw on existing resources: not necessitating large staffs or dedicated hardware systems for the sole purpose of tracking chemicals and emissions. These three requirements are described in greater detail below:

A robust system. The changing regulatory picture has greatly complicated the creation of "durable" software for environmental reporting. The regulatory project manager for Ciba-Geigy in America estimates the rate of change of all environmental regulation at 40% per year. Comparing this to the conventional wisdom of information technologies professionals, which says that one should rebuild from scratch when more than 30% of requirements change, highlights the problem. (Hennessy, 1993) A systems solution to the needs for chemical tracking and emissions reporting must provide data which can be manipulated to meet the requirements of future regulations. This means that the solution will not be defined in terms of SARA, CAAA '90 or any other specific legislation, but rather it will rely on basic principles of material balances. The outputs from these material balances can then be massaged where necessary to fit the guidelines of specific regulations.

A simple system. In many of the discrete manufacturing plants I examined, the persons responsible for environmental reporting were also in charge of a number of other activities with little relation to chemicals and the environment. Such activities included safety,

---

several costly fines and citations for non-compliance. The degree of attention focused on environmental concerns at Hamilton Standard was higher than that of most of the other plants studied.

health, facilities engineering, and human resources management. A good system for chemical tracking and emissions reporting should not be steeped in a lot of environmental jargon which presents immediate barriers to multi-functional professionals. Neither should the system require a computer science background to use and maintain.

A system drawing on existing resources. With the cost pressures which are facing many discrete manufacturers today, it is imperative that a chemical tracking and emissions reporting system be as cost effective as possible: both in terms of the cost of system purchase and maintenance and in the ability of the system to reduce the hours of effort required for tracking and regulatory compliance. After being hit with multi-million dollar non-compliance fines in the 1980's some large facilities in the aerospace and automotive industries have reacted by creating autonomous computer systems for tracking of all chemical transactions, including receiving, inventory, process distribution, air emissions, and waste disposal. These systems, while providing accurate environmental data to prevent further citations, have done so at a cost which could not be borne by smaller, lower-margin facilities.

Many discrete manufacturing plants have installed or plan to install modern manufacturing information systems which provide data for planning and control of multiple operations including purchasing, receiving, accounts payable, MRP (manufacturing resource planning), inventory management, material control, and shipping. An efficient chemical tracking and emissions reporting system should make use of data available in these systems where possible, instead of handling all environment-related data on a stand-alone system. This integrated approach to data management is part of a larger effort to integrate environmental concerns into everyday manufacturing management. It can also help to ensure accuracy of information by providing for a check against multiple data bases.*

In an effort to capture these three requirements, I have developed the model for chemical tracking and emissions reporting presented in the next section. Although most of the requirements listed above are specific to operations in the United States, the data needs for environmental management in other western countries are similar. Further, many western companies try to maintain basic environmental standards at their operations in developing countries even though local environmental laws may be lax or non-existent. In

---

* In an integrated system, a material consumption record will be automatically "checked" by virtue of a periodic inventory balance. In a stand-alone system, such a check would have to be performed manually.

the thesis I have tried to emphasize general lessons rather than those which are specific to the legal statutes of any one country or the policies of any one company. It is my hope that the models developed for environmental management through this research may be seen as generally applicable world-wide.

3.4. *A model for chemical tracking*

An overview of the model which was developed to facilitate chemical tracking and emissions reporting is presented in Figure 3.4.1.

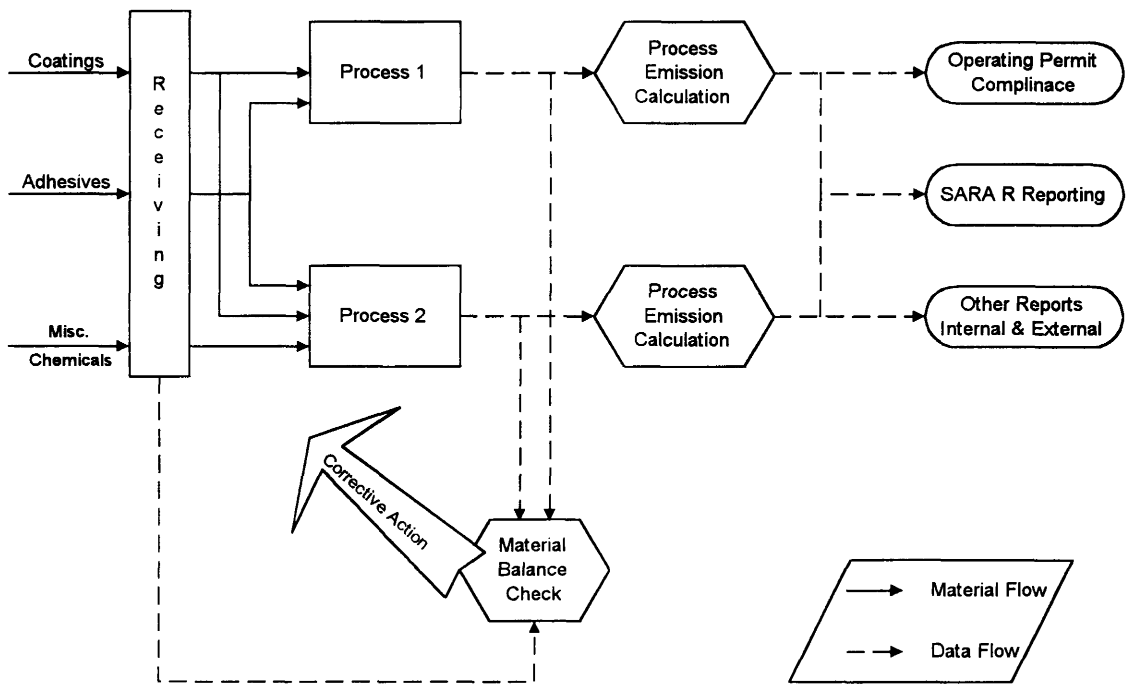

Figure 3.4.1. Chemical Tracking and Emissions Reporting Model

The flows of material and information depicted in Figure 3.4.1 can be understood by looking at the functions through which these flows occur. The explanation of the model which follows will proceed through receiving, materials distribution, process emission calculation, environmental reporting, and data verification.

Receiving. Most manufacturing sites have some kind of central receiving department whose job it is to provide a record of items received into the plant and to make sure that these items are routed to the proper destinations within the plant. Receiving should be the initial point of entry of chemical tracking information as it provides an aggregate view of the gross consumption of material at the plant. (A net consumption calculation will take changes in inventory and resale or return of material into consideration as well.)

Receiving rather than purchasing was seen as the most appropriate place to begin tracking of chemicals since occasionally an item might be "purchased", but never actually delivered or paid for. Also, the timing of receiving data corresponds more closely to the actual material flow than does that of purchasing data (i.e. delay between purchase order and receipt is excluded).

Because of the large amounts of data involved in the receiving of materials, chemical or otherwise, at a plant, most companies depend heavily on computer systems for storing receiving data. These systems may be stand-alone systems or form a part of a larger computer integrated manufacturing (CIM) system. An integrated approach to chemical tracking and emissions reporting should make use of data from the existing receiving system to avoid redundancies in hardware, software, and manual processing.

Materials distribution. Various chemical items will be used at different processes within a plant. Materials distribution data is simply a record of the quantities of various materials which are consumed at each process. This data may be available via distribution records on a CIM system or as part of an organized method of material distribution. Alternatively, it may be necessary to set up a dedicated system for tracking distribution of chemicals to processes, either using some form of electronic system, such as bar code readers and entry terminals, or through use of chemical log sheets at each process.

Process emission calculation. Translation of chemical usage data into an emissions report at a given process is done through a process emissions calculation. For many processes within a discrete parts manufacturing facility, these calculations will be in the form of material balances which separate out the various constituents of a material and then attribute their outflow to various destination streams. Figure 3.4.2. gives a representation of how such an emission calculation works for a paint booth where parts are cleaned with solvents and then coated with paints to which thinners have been added.

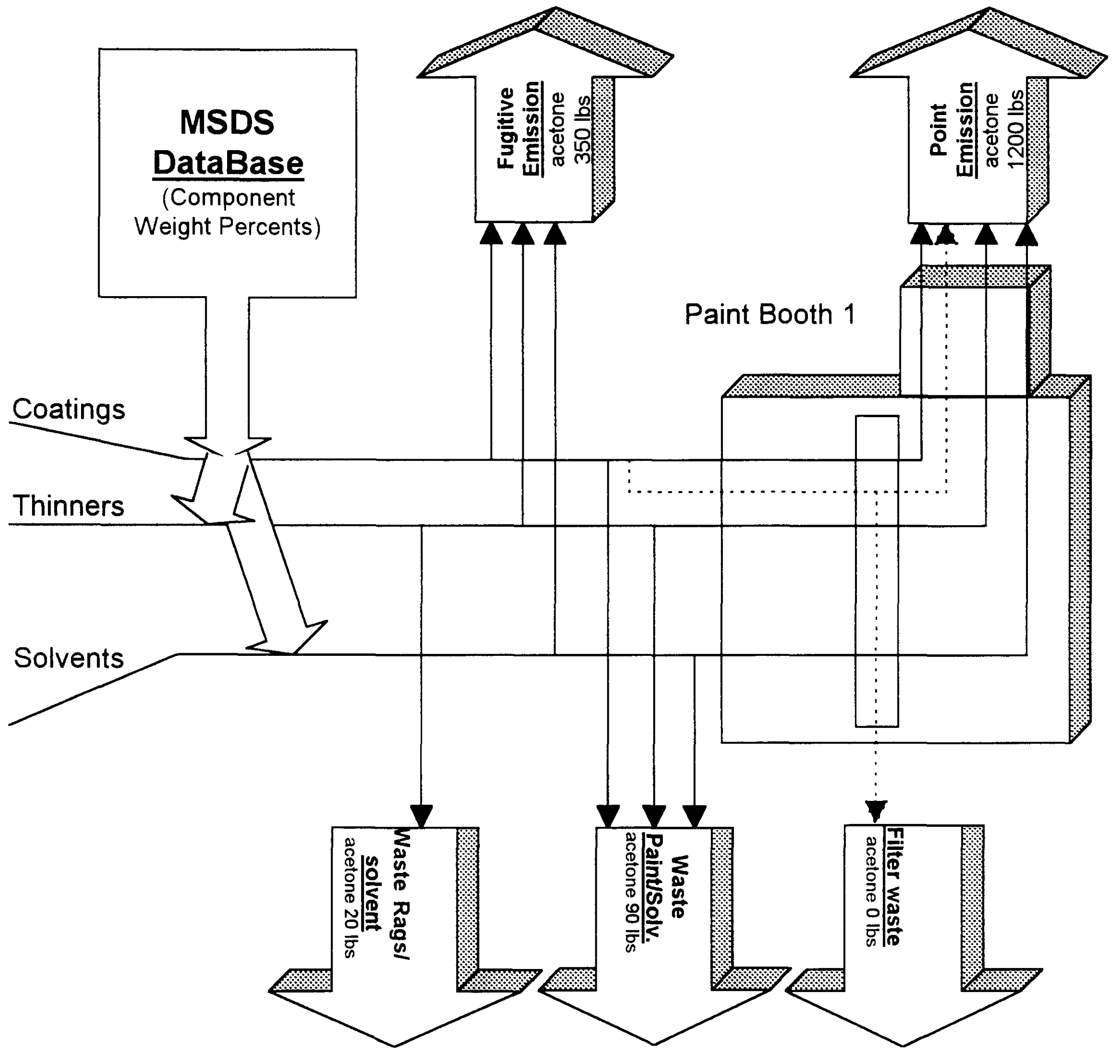

Figure 3.4.2. Graphical representation of process emissions calculation.

For example, a volume of black paint, under the "coatings" category, would first be "exploded" into its various reportable constituents using the information found on a manufacturers safety data sheet (MSDS) Reportable constituents would include any specific EPA listed chemicals as well as general classes of pollutants such as VOC's and particulates. Ten pounds of paint containing 10% acetone would thus yield one pound of acetone constituent under the "coatings" category.

After the "explosion" of materials into components, emissions factors are applied to direct components to the various outlet streams. For instance, it may be estimated that 95% of acetone from coatings will be released to the atmosphere through the paint booth's stack (point emission). The other 5% of the acetone would not be captured by the booth's ventilation system and would be instead released to the air inside the plant (fugitive emission). Other emissions factors or direct material tracking could allow for a complete dispositioning of materials to various other outlet streams such as waste streams or product streams. Figure 3.4.2 shows the entire disposition of acetone from coatings, thinners and solvents to fugitive and point air emissions and various waste streams.

Environmental reporting. The process emissions module of a chemical tracking and environmental reporting system should provide results in a format which can be referenced by an environmental reporting module. In this way, custom reports can be generated for various processes or entire plants, without the need to recalculate or redefine the various input data. Referring back to Figure 3.4.1, one can see the relationship between the emissions calculations of the processes and the various reports which may be required. For instance, Title V operating permits will require reports on air emissions by individual process for a broad class of pollutants such as VOC's. SARA Form R, on the other hand, does not require a process-by-process breakdown of pollution, but does require aggregate quantities of *specific* pollutants such as acetone or toluene. SARA Form R also requires information on amounts of these pollutants released to land and water and transferred off-site for treatment and disposal. The environmental reporting module of a chemical tracking and emissions reporting system should be some type of database shell which allows for report building along a number of query parameters.

Data verification - If a computer integrated manufacturing system is used to handle both receiving and materials distribution, there will most likely be some type of internal balance performed to verify consistency between receipts, distribution, and inventory. If this is the case, no additional effort is required to check on the accuracy of process usage data. On the other hand, if another system, such as manual log sheets, is used to provide process usage data, then a material balance check should be included as a part of the chemical tracking system. Such a check might consist of a periodic comparison of receiving data for each chemical item with the total quantity of that item recorded on individual process log sheets. This type of verification should catch any instances where chemicals are evading the tracking and reporting system and it will ensure the quality of the plant's environmental data.

In this chapter I have developed a model for a chemical tracking and environmental reporting system. Chapter 4 describes the actual implementation of such a system.

4. Implementation of the Chemical Tracking Model in Industry

In the last chapter a basic model of a chemical tracking and environmental reporting system was presented; now the implementation of such a system will be considered. As noted earlier, efficient implementation will make use of existing data and data handling systems where possible and will not rely on a large environmental management staff to maintain data integrity. The idea of integration of environmental responsibility throughout the different functions and levels of management is key; it is simply not cost effective to have a large environmental group running around the plant trying to make sure that data is being accurately recorded. When environmental stewardship is seen as part of everyone's job, the persons closest to the various business and production processes will maintain the accuracy of their part of the data.

The main site which I was able to draw implementation lessons from, Otis Elevator's Bloomington, Indiana facility, was an especially interesting one for several reasons. First, the custom nature of much of Otis' work meant that there was a large and complex variety of chemicals and processes to deal with. More than 400 different chemical products required tracking at least at the aggregate level. Secondly, since increased market competition was focusing managers' attention on cost reduction, the implementation of an expensive and manpower intensive tracking and reporting system was out of the question. Finally, the Otis Bloomington facility was in the midst of bringing a new computer integrated manufacturing system on line to handle a number of activities including purchasing, receiving, inventory, and manufacturing resource planning. This transition presented an opportunity to define a number of the system parameters in order to provide meaningful data for tracking purposes.

The first section of this chapter contains a discussion of some basic steps which must be taken to lay the groundwork for a tracking and reporting system. Next, the collection of aggregate material usage data from a receiving system and the generation of usage data for specific processes is described. After this, two parts of the emissions calculation function, input of component data and building of process models, are outlined. Lastly, issues relating to the maintenance and continuity of the system are discussed. Some of the barriers and challenges to the implementation of a chemical tracking and environmental reporting system are discussed in the conclusions chapter.

4.1. *Laying the groundwork for a tracking and reporting system*

Before a plant can attempt to implement an integrated chemical tracking and environmental reporting system, four basic steps must be taken to ensure efficient implementation and complete data. The reader whose plant has already satisfied these requirements may choose to proceed to the next section; the four basic items required are listed below:

- List of chemicals purchased
- Control of chemical purchasing
- Flags on chemicals in name or part number
- MSDS database

Each of these four basic requirements is described in detail below:

List of chemicals purchased. A first step in implementing a system for tracking and reporting is to get a list of all products currently used at the facility which contain components which *might* need to be reported under existing or proposed legislation. This would include specific pollutants such as lead or benzene as well as general categories of ingredients such as volatile organics. Such a list should incorporate not only items which are specifically applied to a plant's output, but also materials which are used for maintenance and sundry activities. This list will be the basis from which tracking of chemicals will be initiated.

Control of chemical purchasing. Once a list of chemical products is created, it is necessary to ensure that new chemical items will not miss being placed on the list. It is crucial that an established procedure be maintained for requesting and purchasing new items. Such a procedure might have several parts such as getting *approval for use* from the environmental manager, obtaining a material safety data sheet for the proposed item, and requesting the item through a purchasing agent designated to handle all chemical purchases. (This purchasing agent might also be the owner of the list of chemicals purchased.) In a plant with numerous departments and tens or hundreds of individual processes, failure to enforce a singular procedure for purchase of new chemicals will make it very difficult to ensure completeness of data from a tracking and reporting system.

Flags on purchased chemicals. Once a list of chemicals has been established and chemical purchasing has been brought under control by procedure, a further step, that of flagging chemicals by name or part number, may be taken. For example, instead of assigning a chemical item the same type of part number as a discrete part, a specific format might be used to set these items apart. At the Otis plant, the prefix "HC" (hazardous chemical) was added to all item names so that they would be easily identified both in use and for tracking purposes. Even when item names are used instead of part numbers, the use of a flag can greatly simplify the aggregation of data on chemical purchases and receipts. For instance, "Black Paint" is easily lost between "Belts" and "Black Paneling" in a list of thousands of purchased items. (For more information on this subject, see Figure 4.2.1.)

MSDS database. A last item which may greatly facilitate the task of tracking and reporting for a plant that uses a large number of different chemical products is the creation of a database of all material safety data sheets for chemicals used in the plant. By law, manufacturers are required to have MSDS's available on demand to workers. Entry of the MSDS information into a database can satisfy this legal requirement as well as serve as a home for the purchased chemicals list and various data on chemical composition and physical properties which are required for environmental reporting purposes.

With these four basic steps in order, the groundwork is laid for a chemical tracking and environmental reporting system which will satisfy both internal and external needs for data. Through establishment of a chemical list and procedures for purchases of new chemical items, several functions outside of environmental management will have gained an understanding of some of the data requirements of environmental reporting as well.

4.2. *Automation of aggregate level data*

The first level of data collection represented in the model presented in Chapter 3 is the aggregate or plant-wide level. (Refer to Figure 3.4.1.) There are two basic cases to consider for this process: a facility which uses separate purchasing systems for different departments or functions, or a facility which handles all materials purchasing under a single unified system. At the Otis plant, we had a chance to examine both cases because they were transitioning from the first case to the second. In either case, it is assumed that currently most plants will be using some form of computer-based method(s) for handling receipts of materials. Thus the "collection" of data is performed by a computer - what is important then is the configuration of the system(s) to allow chemical receipt reports to be generated.

System configuration consists of both a one-time "lining-up" of all chemical items for automated tracking, as well as establishment of a process for getting new items into the data loop. The initial line-ups and the process for continuation are described in turn.

4.2.1. Initial line-ups for automation of data

A fundamental first step in automating the aggregate data collection is establishing a protocol for naming all chemical items. These names will be used by information systems such as the purchasing or MRP systems as well as by plant personnel, to identify chemical items as such. The protocol which was established at Otis is shown in Figure 4.2.1.

HC designator HC# description of purchase UM

Name => H C x x x x y y y y (y y y ....)

Digits => 1 2 3 4 5 6 7 8 9 10 11 12 13 ......

Examples:

HC00031OZ - this is the 16.5 ounce can of HC#3. The purchase, stocking, and selling UM's are "EA".

HC00461GL - this is the 1 gallon can of HC#46. The purchase, stocking, and selling UM's are "GL".

Figure 4.2.1. Protocol developed at Otis Bloomington for naming chemical items

The Otis protocol serves three main functions. The first two digits are the "hazardous chemicals" flag which allow for quick identification of these items as needing to be tracked. (These items are not necessarily *hazardous* in the strict sense - the label was chosen out of convenience.) The next four digits contain the number of the material as assigned on the purchased chemicals list. This number links the item to a specific material safety data sheet and hence to specific physical and chemical properties. Finally, the last set of digits contains a description of the purchased quantity or *unit of measure* (UM) for the item. This allows for an eventual conversion of units to a standard unit for reporting purposes such as gallons or pounds.

For the case where multiple purchasing systems are used at a facility, use of a standard protocol for naming chemical items will help to ensure continuity of data across the various systems. Ideally, the conversion of purchased units (drums, cans, etc.) into reporting units (gallons or pounds) should be performed on the individual systems so that this information will be visible to the purchasers of the chemicals and so that the ownership of this data will rest with the parties who actually use or handle the material. The conversion of units could be handled on a single system residing with the environmental management function. However, this approach tends to leave environmental managers with the dubious responsibility of ensuring data accuracy - something which goes against the principle of integrating environmental responsibility across functions.

At a facility where a single purchasing system is used for all material purchases, the naming protocol can be used in conjunction with a unit conversion program to automatically provide information on receipts of all chemical items in standard units. (i.e., Purchases would be totaled in standard units such as pounds or gallons rather than the typical purchasing units of measure like cans, tubes, drums, or "each".) At Otis this type of solution was implemented. Standard "reporting units" of gallons for liquids and pounds for solids were chosen. A generic unit conversion table was created in the CIM system for standard conversions such as quarts, pints, or 55 gallon drums, to gallons, and ounces to pounds. For items which came in non-standard quantities (i.e. 2.5 ounce tube with unit of measure "each"), item-specific conversion tables were created to allow these items to be converted to standard units. Code was written inside the CIM system to allow various chemical queries and reports to be performed using these generic and item-specific conversion tables. As a result production managers, buyers, and EH&S staff could quickly generate custom reports on quantities of chemicals received at the plant - a task which had previously required a great effort.

Certainly it should be noted that close cooperation between a number of functions is required to set up this part of the chemical tracking system. At Otis, EH&S, purchasing, manufacturing engineering, and MIS groups all played important parts in setting up the aggregate receiving data capability.

4.2.2. A process for introducing new chemical items

Given the number of different departments within a manufacturing facility which work with various chemical products, a routine process should be followed for introducing new chemical products into use. Some of the steps in such a process, such as consideration of health effects and safe usage, pertain mostly to the actual chemicals contained in the product, while others such as lining-up unit conversions for chemical tracking, pertain to the product/purchase-quantity combination. (Here, the term "chemical product" is used to refer to the chemical composition, while the term "chemical item" refers to the product/purchase-quantity combination. Chlorox™ bleach would be a "product", while 32 ounce and 1 gallon containers of Chlorox™ Bleach would each be a separate "item".)

The procedure that was implemented at Otis Bloomington to ensure continuity in reporting of receipts for new chemical products and items is shown in Figure 4.2.2. In creating this process, an effort was made to keep the ownership of the various tasks with the persons closest to that task.

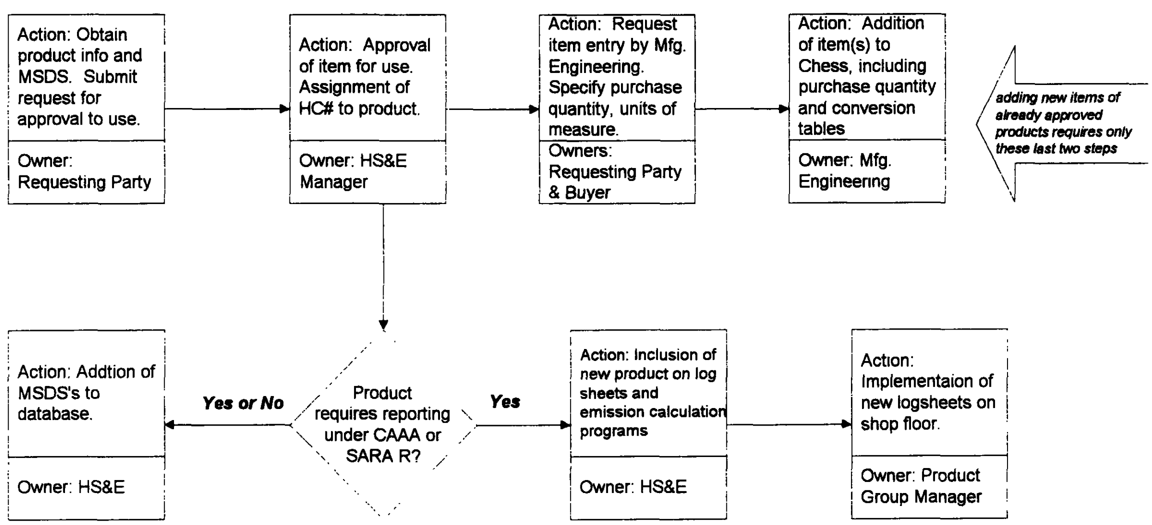

Figure 4.2.2. Procedure for Introduction of New Chemical Products and Items

The requesting party, usually a manufacturing engineer, begins the process by obtaining a material safety data sheet from the prospective vendor. She then submits the MSDS to the EH&S manager with an "approval for use" form which provides a brief description of where the material will be used and in roughly what quantities. The EH&S manager must approve the item for it to be brought into the plant. After EH&S approval, the requesting party, in cooperation with the buyer, is responsible for having the product lined-up in the manufacturing purchasing and control system. This line-up will then be performed by the manufacturing engineering department according to the protocol described in Figure 4.2.1. At the same time, the EH&S manager must determine if use of the product will require reporting under state, federal, or local requirements. In either case, material safety data must be entered into the MSDS database by the EH&S department. If reporting is required, the product must be included on process log sheets and these new log sheets must be implemented at their respective processes. (Chemical reporting and log sheets are described in the next section.)

For the case of a new item of an existing product, the only steps necessary in this process relate to the addition of a new line-up in the purchasing system. The EH&S department need not necessarily be consulted for such a change, and providing that the new item is lined-up properly, the aggregate receiving data for the new item should be available in proper reporting units.

4.3. *Collection of data at the process level*

In order to collect chemical usage and emissions data for specific processes at a manufacturing facility, a record of which chemicals are used at each process must be developed and a method for obtaining timely and accurate usage data for each process must be established. These two issues are described in this section.

4.3.1. **Initial survey**

Before chemicals can be tracked and emissions reported on a process by process basis, some basic data must be established for each location at which chemicals are used or emitted. Thus the starting point for this level of data collection is some type of plant survey to find out which products are being used at various locations. At Otis, this initial survey was accomplished by an extensive "walk-through" of all areas of production. From this survey two general types of processes emerged: 1)"Major" processes, those whose primary task involved application or other use of a chemical product, and 2) "Minor" processes, those processes where small quantities of chemicals were used in some auxiliary function. Major processes included surface coating, motor varnishing, and application of adhesives. Minor processes included such things as hand wipes (use of a solvent-wetted rag for wiping a part), touch-up spray painting, and use of adhesives in shipping. It was determined in conjunction with the Indiana Department of Environmental Management that these minor processes would not need to be reported individually, but rather that chemical usage and resultant emissions for all minor processes could be grouped under a "miscellaneous" category for the facility's operating permit. Thus, from a tracking standpoint, only the major processes required individual records.

4.3.2. **Methods for routine collection of process data**

Once the initial chemical use survey is completed, a method must be set up to provide usage data for compliance certification and periodic reporting needs for each of the noted processes. Two general methods were examined for satisfying the data collection requirement. The first method consisted of creating customized process log sheets for each major process. Operators would then record usage of chemicals on these logs and these records would be manually transferred from the logs to the tracking and reporting system on a periodic basis. A second method would utilize bar-code technology to track the movement and use of chemical products throughout the plant. This type of system would provide for automatic transfer of data to the tracking and reporting system and could be tied into the plant's computer integrated manufacturing system.

Log sheets. The log sheet based method, which was the method chosen at Otis, had a lower implementation cost and was able to be implemented immediately. (A bar-code system would have required a considerable capital and human resource investment and would have taken four to six months to implement.) In the case of Otis, 13 "major" processes were identified and thus 13 custom log sheets were developed for use. Figure 4.3.2. shows a simplified example of one of the log sheets in use at Otis.

Month:	January		**Otis - Tracking Log Sheet**				
Process:	Primer Booth			Notes: Record whole container when seal is broken.			
Location:		G18		All records in gallons.			
		Paints		Thinners		Solvent & Booth Coat	
Date	Operator	HC110 Black Bake	HC589 White Bake	HC015 Xylene	HC022 SS Blend	HC022 SS Blend	HC129 Booth Coat

Figure 4.3.2. Simplified Process Log Sheet from Otis Bloomington Tracking System

Each process log sheet covered one month's worth of data and provided a place for operators to record their name and the use of specific chemical products.* This logging of products did not represent a substantial burden on the operators as only one to two entries per shift was required on average. At the end of each month, the process log sheets were sent to the environmental department to be tallied and entered into the tracking and reporting system. Ideally, these tallies would be maintained by the production departments so that they would have a better idea of their consumption of chemicals and awareness of cost reduction opportunities. Otis will likely move in this direction in the future.

Bar-code system. A bar-code based system would make use of bar-code printers and readers with a link to the tracking and reporting database to eliminate the need for manual entry of tracking data. The bar-code method would proceed as follows:

1. An item-specific bar-code label would be printed and affixed to each item upon receipt by the receiving department; the weight of the item would be recorded

2. Upon disbursement of the item from receiving to a storage location, the item would be scanned and deducted from receiving, and scanned and added at the storage location

3. Upon removal of the item from the storage location to a process, another set of transactions would be recorded, charging the use of the item to the process

4. When use of the item at the process is concluded, the container would be reweighed and the final weight would be deducted to give the net usage

While the bar-code based method does provide a more rigorous accounting for each transaction involving chemicals, the use of such a method entails considerable installation and operating costs for bar-code printers and terminals. In order to be effective, these

---

* In most cases, rather than recording the exact usage of a product per shift (i.e. using dip-sticks to measure differences in drum levels), the convention was adopted of logging usage of an entire container at the time the seal was broken. In fact, this convention proved satisfactory as long as the time required to consume a container was short compared to the required reporting frequency.

terminals would need to be located at each process. While in our estimation the cost of this type of system did not warrant its use at the Otis facility, there are two occasions where such a system might prove necessary. First, the regulatory climate at a location could be particularly stringent, such that the frequency of reports and the timeliness required would make the use of manual log sheets untenable. Alternatively, a bar-code based system might be deemed necessary for *all* items, including chemicals, for material control purposes. In this case, the chemical tracking requirement would be the beneficiary of a general material control emphasis.

4.4. Emission calculation, reporting, and material balance check

Overview of the approach. Through this point in the described implementation, extensive use was made of computer systems and data which resided outside the environmental management function. Now, where a translation from material usage data to emissions estimates is required, the implementation begins to rely more on programs designated for this specific task under the control of the environmental staff. Figure 4.4.1 shows the chemical tracking and emissions reporting model from Chapter 3 with boundaries shown for the various systems according to the implementation plan at Otis. The largest shaded region, entitled "Environmental Management Software", represents the scope of the tasks included under the environmental staff.

During the investigation of possible solutions to the data needs at Otis, a variety of approaches to handling the tasks covered in the largest shaded area were considered. On this subject a fair amount of informal data about the types of systems that various other manufacturers were using was also obtained. The most common approach was that of purchasing a canned software package with modules for different types of emissions calculations and various report forms. Software packages of this type were being installed at various locations of Hamilton Standard, DuPont, AlliedSignal, and General Motors to name a few. In addition, at some of these locations the environmental management software was extended to handle the gathering of aggregate and process level data (Hamilton at Windsor Locks, Connecticut) or to receive direct input from these systems (DuPont, multiple locations). For the Otis implementation a product comparison was performed for about a dozen software packages resulting in three of these packages

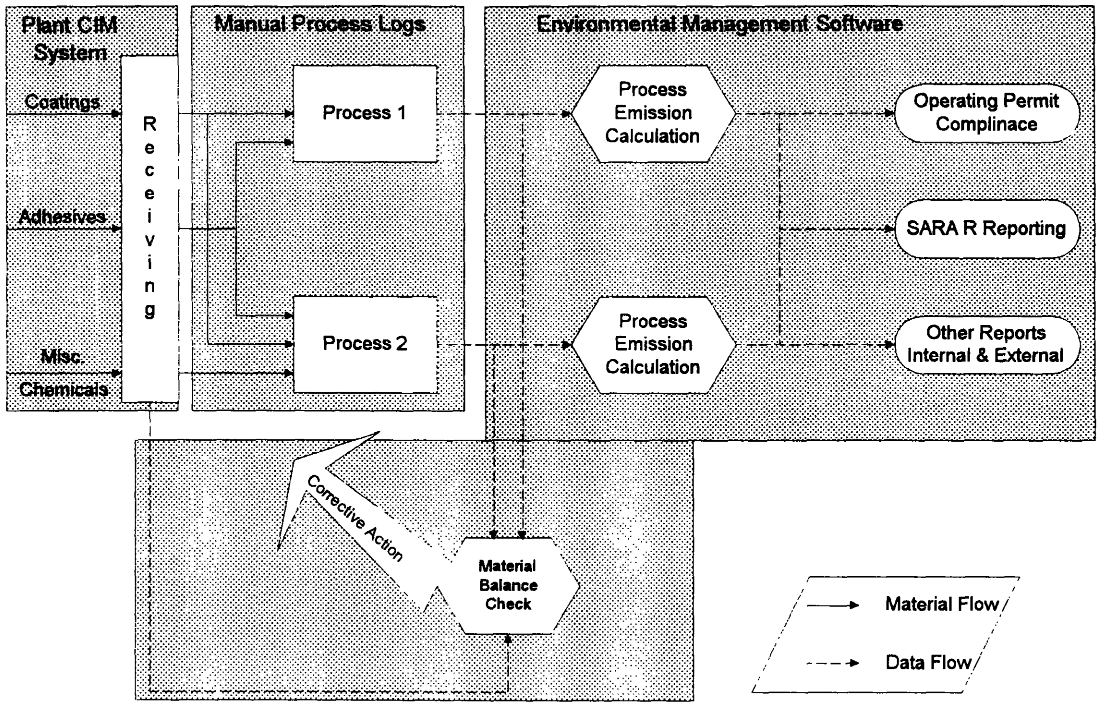

Figure 4.4.1. Chemical tracking model with scopes of various systems included

being selected for testing at Otis.* In any situation involving the use of a canned package, the compatibility of the package with the existing plant information systems is of major importance.

Some firms believed that their specific environmental management needs warranted the in-house development of environmental software. For example, Digital Equipment Corporation was in the process of developing comprehensive environmental software for use at all of its manufacturing locations. As the type of emissions calculations required may vary somewhat from location to location, and given the fact that the computational logic is fairly simple, the site (or company) specific development of environmental programs can be accomplished with some efficiency. However, use of a commercial package has a number of advantages such as availability of literature and technical support as well as periodic upgrades reflecting systems and regulatory developments.

* The packages reviewed were "i-Steps" by Pacific Environmental Services, Research Triangle Park, NC, "Quantum" by Quantum Compliance Systems, Ann Arbor, MI, and "Logitrac" by Logical Technologies, Peoria, IL.

Finally, a number of the manufacturing locations queried were behind Otis in the implementation of environmental systems and their approaches were only partially defined or in some cases nonexistent.

Most of the commercial packages considered were built on some sort of database engine such as FoxPro by Microsoft. Given the amount of data which needs to be stored and manipulated in a typical installation as well as the need for data integrity, some sort of database software is almost certain to be the best fit.

The plan at Otis was to purchase in early 1995 one of the commercial packages tested. (It was decided to hold up software purchase until a new full-time environmental engineer was brought on board to set up and run the system.) In order to bridge this gap and so that all necessary system requirements could be determined, a temporary emission calculation and material balance check was set up using a Microsoft Excel 5.0 workbook. This workbook included most of the components which would be contained in the eventual environmental software with the exception of forms for specific government reports. Since the application of software to environmental management will vary from site to site, and because many sites will likely choose to purchase a package to perform this function, the software design will not be discussed in detail in this thesis. However, some information on the basic program architecture is provided in the paragraphs that follow.

Basic software architecture. Whether the plant environmental management software is developed in-house or purchased from a software company there are a number of essential components which are likely to be included. Figure 4.4.2 shows an architecture for a tracking and emissions reporting program similar to the one planned for Otis. The blocks shown in the figure are of three different basic categories: 1) Data gathered from daily plant operations, 2) Parameters reflecting the nature of products or processes, or 3) Calculation modules which manipulate data from the first two categories.

The first block of data shown in Figure 4.4.2, that of "Gross Chemical Usage Data", contains the amounts consumed of the various chemical-containing raw materials at individual processes. This data could be transferred automatically into the database if a bar-code based system is used to gather the process level data. In the case of the Otis implementation where log sheets were used, this data had to be entered manually into the prototype Excel workbook.

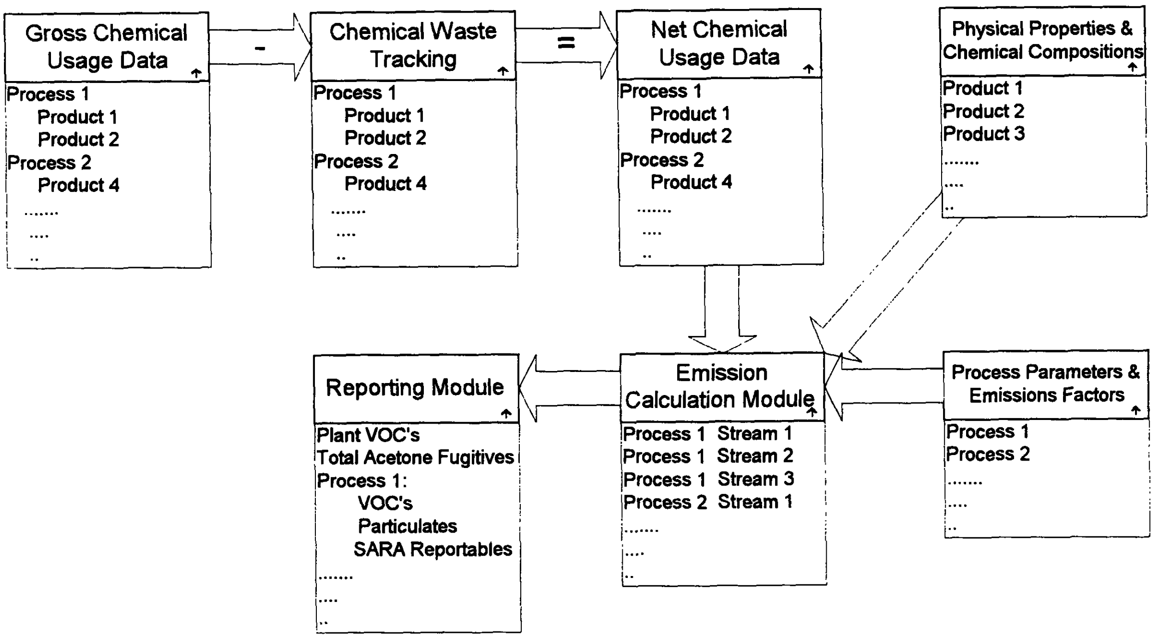

Figure 4.4.2. Essential components of tracking and emissions reporting software

A summation of the gross usage data over the whole facility by individual chemical item provided the material balance check referred to in Chapter 3. (e.g. The total amount of black acrylic enamel recorded at the individual processes was compared to the total receipts provided by the CIM system over a set time period. Significant variances could then be fleshed out and necessary adjustment made.)

If chemical waste streams are tracked by individual process and if some idea of the composition of the waste streams is known, a "netting" (gross usage less contribution to a waste stream) can be performed to reduce the quantity of material calculated as emissions. This process is represented in the figure by the minus sign in the arrow connecting the "Gross Chemical Usage Data" box to the "Chemical Waste Tracking" box. The result of this process is the "Net Chemical Usage Data". This type of netting may be deemed necessary when the quantity of wastes is large compared to the emissions (i.e. waste : emissions greater that 1:10) or when emissions are running at or near permitted limits.

Once the net chemical usage has been arrived at, a series of calculations are performed in what might be called an emissions calculation module. The emissions calculation module performs the transactions which were earlier described in Figure 3.4.2; the order of these calculations proceeds as follows: First, the net chemical usage data is merged with physical properties and chemical composition data to convert raw material volumes into specific weights of individual chemical constituents. For example, ten gallons of a certain thinner (50% toluene, 50% xylene, density of 8 pounds per gallon) would be multiplied by its density to give eighty pounds of thinner, then multiplied by composition to yield forty pounds of toluene and forty pounds of xylene. The chemical streams are then multiplied by process parameters and emissions factors to generate emissions flow rates in terms of individual chemical entities for the various emissions points. For instance, the configuration of a paint booth might indicate that 90% of all vapors released in the area of the booth will be exhausted through the stack system. Then for the point emission source associated with the stack, one would have 36 pounds of toluene and 36 pounds of xylene emitted from ten gallons of thinner. (A fugitive source of 4 pounds of toluene and 4 pounds of xylene would also be indicated.) If emission abatement equipment was installed on the stack, an emissions factor would be included to account for the reduced chemical discharge.

The last module shown in Figure 4.4.2 is the reporting module. This module is a sort of a data base shell where values determined in the emissions calculation model can be arranged into custom reports by using various report queries. The advantage of having a flexible reporting module rather than just a list of fixed output reports is that new reports can easily be configured to satisfy both internal and external demands for different types of data. This could be helpful for reporting to satisfy new government regulations as well as for supporting internal environmental improvement programs.

4.5. Early results of the chemical tracking implementation at Otis

Despite the fact that the full implementation of the chemical tracking and emissions reporting system will not be complete at Otis Bloomington until the first half of 1995, the part of the system which was in place in December was already allowing for a much improved efficiency in terms of data gathering and handling. In early December, a mock-SARA report was run to test the system and to compare 1994 numbers with those which had been reported for 1993. As was mentioned earlier, the 1993 report required approximately 300 technical man-hours for data collection and emissions calculations. The time required to process these tasks for the through-December data this year was approximately 60 hours. However, this number was even somewhat inflated by the fact that approximately two-thirds of the time was spent collecting data from the first part of 1994, the time prior to the system's implementation. The fact that one can quickly determine the use of chemical products (and therefore an estimate of emissions) on a real-time basis will allow the plant's management to be more quickly aware of potential increases in emissions or waste transfers and should reduce the likelihood of costly end-of-the-year surprises.

Since now the main data-gathering aspects of the tracking system are included as part of the plant's overall computer integrated manufacturing system, the practice of collecting environmental data was both automated and tied to the core business practices of the plant. No longer must someone with an environmental hat go back into the past and try to figure out what the operations people did six months or a year ago. As items are transacted in the CIM system on the shop floor, a transaction history is created which is available on demand to the production staff as well as the environmental staff.

Finally, with the commencement of the process log sheets, the environmental staff at Otis was able to follow the use of chemical products and the emissions of various chemical components by process on a real-time basis for the first time.

This chapter and the one preceding it have described the development and implementation of a chemical tracking and emissions reporting system. In order to obtain maximum benefit from the data which this system provides, we need a method to translate environmental impacts into financial terms. This subject is addressed in Part II which follows.

Part II. Incentives for plant environmental performance

A common problem with the implementation of environmental management practices and systems at manufacturing facilities in America has been the sometimes intermittent nature of management commitment. One veteran environmental manager that I met at a conference stated, "95% of the time management doesn't want to be bothered by environmental issues, the other 5% of the time, when there is a fine or a workers comp case or a leak, management wants to hang someone".

As has been mentioned in the introductory chapters, the major theme of this thesis is to discuss ways to integrate environmental management into the business of discrete manufacturing. Part I of the thesis has presented a view into how the improvement of information systems for providing data on environmental impacts of a manufacturing operation can both save money and contribute to good decision making on environmental issues. Part II will take this one step further by exploring how the conversion of environmental data into financial terms can help to integrate environmental decisions into the strategic decision making of a company.

5. The environmental economics of manufacturing

5.1. Breaking down barriers between sound financial management and environmental management

Does being a "green" company require financial sacrifice, or is it the only viable strategy for future growth? Are all pollution prevention projects really "strategic" in nature, implying that they will pay out in the long run? There is a lot of verbiage in environmental journals about these issues, but how should plants evaluate pollution prevention projects? If environmental management is to be truly integrated into the business, environmental projects must be evaluated in the language of business - namely money.

Presently there is a dichotomy between the evaluation of environmental projects and the evaluation of other projects which are seen as "core to the business". It has been proposed that since pollution prevention projects are typically seen as "must-do" projects, they are automatically categorized as costs of doing business and thus no analysis of benefits is performed. (White, et al, 1993) A "bias" against pollution prevention projects described by these authors comes from the fact that many of the benefits of an environmental project are second or third order in nature and are therefore left out when projects are evaluated over too short of a time horizon. These benefits would include things such as the enhancement to brand image of an environmentally responsible reputation.

I would take these observations one step further and emphasize a communication gap between environmental management and financial management. While business managers focus on such monetary measures as revenues, costs of goods sold, overhead expense, return on investment, and net present value, environmental managers focus on what "has to be done". The language of environment is "tons of VOCs", "pounds of RCRA waste", "life cycle impacts", "compliance", and other terms which are well understood by environmental managers and government regulators, but seldom clear to plant managers and engineers. Once the operating managers have become sufficiently confused by the environmental language surrounding a project decision, they simply ask the question, "do we have to do this project to avoid fines or a shutdown?" If the answer is "yes", the project is done, if the answer is "no", the project is dead. Hence there is a real need to put environmental projects in the same terms as other projects so that managers can make informed decisions on capital investment issues. And if pollution prevention projects are to compete for capital, it is imperative that all potential benefits of these projects be brought out in a sound financial analysis.

The idea of seeking out all costs, including environmental costs, which are relevant to a product or process decision has been dubbed "Total Cost Assessment". (White, et al., 1993) Although this term might be original, the idea of considering all relevant costs when making a managerial decision is hardly revolutionary. However, for a variety of reasons, environmental costs are sometimes "hidden" and historically they have been left out of many capital expenditure decisions. Thus, the issue of cost assessment has recently been taken up enthusiastically by the environmental field. At a recent conference of environmental and engineering managers from across United Technologies' operating divisions, the topic of economic analysis of pollution prevention was addressed exclusively in two presentations and was included in many others. The message was clear that environmental projects will have to compete more and more with other projects for capital funding. Total Cost Assessment will be key to allowing these projects to compete.

The goal of Total Cost Assessment (TCA) is to bring out all relevant costs, including environmental costs, through two main thrusts. First, all costs which are incurred as a result of production must be included in the assessment. For example, the cost of labor for a process should include not only the labor involved in running the process, but also labor for maintenance, setup , supervision, engineering, waste handling, etc. Often these indirect costs span several departments and the sum of these costs can overshadow the direct labor element. Secondly, a complete TCA should attempt to put numbers on other "intangible" costs such as the cost of insurance , the potential future liability from hazardous waste disposal, or the effects of pollution on the image of a firm.

The economic evaluation of pollution prevention projects and environmental policy in the manufacturing environment is examined in the rest of this chapter. First, the classical cost accounting model which forms the basis for most plant accounting systems is described and its failure to motivate economically viable pollution prevention projects is discussed. Next, a case study of a pollution prevention project at the Otis Elevator Bloomington Plant is presented as an example of the use of Total Cost Assessment methodology to bypass the inadequate accounting system. The estimation of some intangible costs is brought out in this case study, with the estimation of future liabilities for hazardous waste disposal treated in a separate section. Finally, the use of activity based costing and another technique, chargebacks, are described as ways of incorporating Total Cost

Assessment methodology into the cost accounting system in order to improve the continuity of decision making.

5.2. *The purpose of cost accounting*

Cost accounting, also called management accounting, is the *internal* accounting system whose purpose is to provide both routine information for the planning and control of operations and special information for strategic and tactical decisions. (Horngren & Foster, 1991) This functionality is depicted in Figure 5.2.

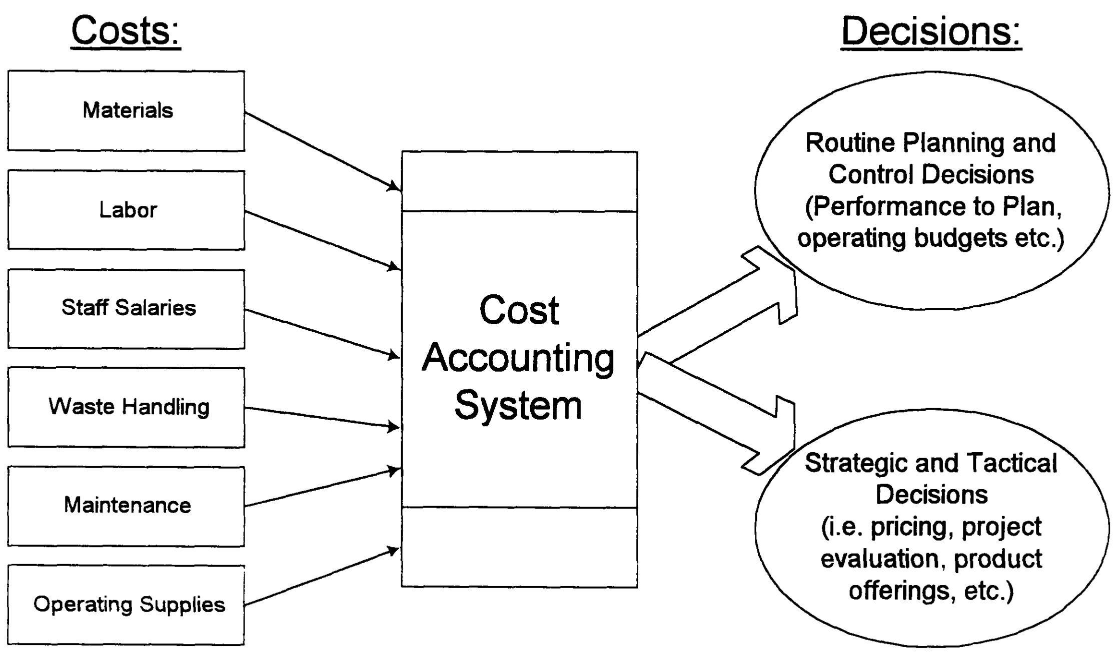

Figure 5.2 Functionality and purpose of cost accounting systems

In the case of incentives for pollution prevention, we are primarily concerned with this second purpose, that of providing information which will allow managers to answer questions such as:

- what is the true cost of a product or process? , *and*
- what prices should we charge for our various products?
- which items should we make and which should we outsource?
- which raw materials have the best cost/benefit characteristics?

- which auxiliary items lead to the lowest overall operating costs?
- should we invest in a new process to replace an existing one?

Without an effective cost accounting system to answer these questions in an efficient and accurate manner, managers cannot make the decisions which will most benefit the firm. It should be noted that this issue expands far beyond the bounds of environmental project evaluations.*

Critical to the accounting of environmental costs, is the assumption that one knows the sources of these costs. This is why an accurate chemical tracking system was deemed a prerequisite for true environmental cost accounting in Chapter 2: just as one could not hope to know the cost of materials for a product without knowing which parts went into that product, one cannot know the environmental related manufacturing costs of a product without understanding the flow of chemicals involved its production.

So what exactly is the relationship between cost accounting and capital budgeting or project evaluation? Cost accounting systems provide financial information on products and processes on a regular (daily, weekly, monthly, quarterly) basis and are the primary input to operating decisions. The information from cost accounting provides the spark for the conceptualization of cost reduction projects to which resources are then allocated in the capital budgeting process. In other words, a cost-reduction project begins with the discovery of unnecessary costs, and this is either aided or hindered by the cost accounting system. If we are to initiate and advocate pollution prevention projects by means of economic data, we must first understand the ability of cost accounting systems to deliver that data.

5.3. Economic analysis under a traditional cost accounting system

In section 5.1 it was mentioned that environmental costs are often "hidden" costs, and that these costs are often left out of important managerial decisions. Where exactly are these

---

* In their book, Relevance Lost: The Rise and Fall of Management Accounting, Robert Kaplan and Thomas Johnson chronicle the evolution of classical cost accounting and argue that it is poorly suited to provide relevant information to managers today. (Johnson, et.al., 1987) They emphasize the availability of modern information technologies which can potentially deliver more accurate and specific information through the use of activity based costing. This topic is described in more detail later in this chapter.

hidden costs to be found? From the work performed at Otis as well as a survey of other project evaluations I have concluded that important environmental costs are often hidden in three areas: as department expense items, as general facility overhead items, or as intangible costs. In order to more completely describe this situation, an explanation of the underlying accounting systems is necessary.

Types of costs: In a traditional cost accounting system such as that found at most of the operating facilities surveyed for this work, there are four main categories of cost accounts. (See Figure 5.3.1) The first type of costs, *direct costs*, are the most straightforward to track and to comprehend. Direct costs include items such as parts, subassemblies, and sometimes labor *units*, such as minutes per assembly step. A simple example of a direct cost item and its allocation to a product is the cost of the tires on a car. Four tires would be purchased for each car, and the cost of these tires is a finite figure which can be readily assessed to the final product via a bill of materials for the car. In a similar way, if the amount of labor required to perform an operation is readily definable (i.e. on an assembly line with a fixed rate), the cost of labor for that operation can be assessed directly to the resulting product. Direct costs are almost sure to be included in financial analysis since they are generally both a major component of the total cost of a product, and their contribution to total cost is easily measured.

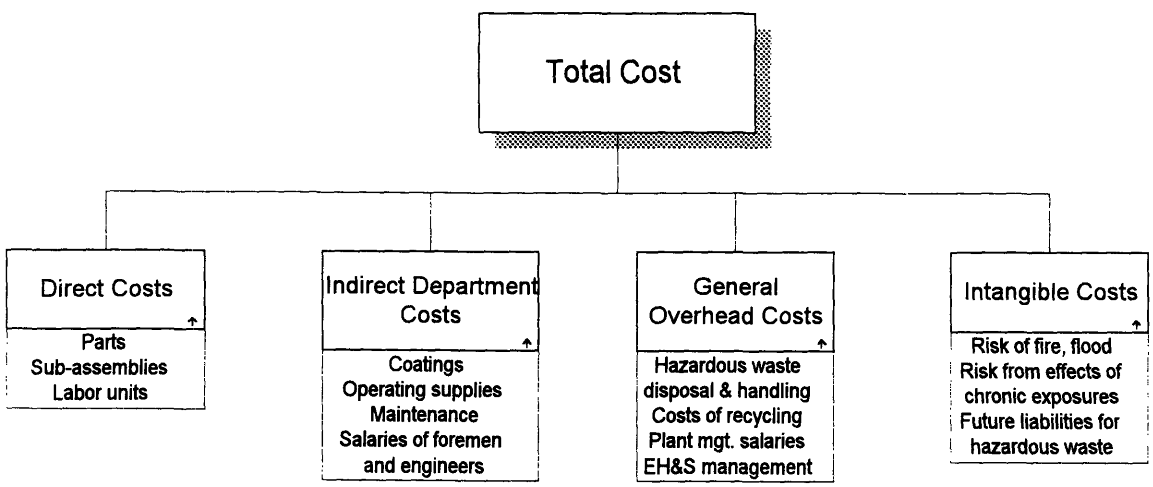

Figure 5.3.1 Cost categories and examples of cost items in traditional cost accounting

A second type of cost, *indirect department costs* or *department expenses*, consist of costs which are incurred by a specific department and are charged to that department, but are not directly linked to specific items produced in that department. Common examples of this type of cost would include coatings and solvents, machine maintenance, consumable parts (i.e. grinding wheels), indirect labor, and supervisory labor. The allocation of these costs to products is described in the next section.

General overhead costs are costs incurred at a manufacturing site but not directly associated with a specific department or departments. These costs might include handling and disposal of hazardous wastes, facilities maintenance, staff salaries, and plant environmental, health & safety costs.

A fourth type of costs, which is often overlooked or only partially included under other categories of costs is *intangible costs*. Examples of intangibles might include the risk of fire, risk of ill-health of workers due to chronic exposures, future liabilities from hazardous wastes, and the effects on a company's image of a pollution problem. Sometimes these intangibles are included in the general overhead accounts of a facility, as is often the case with fire insurance, but they are often omitted altogether.

Next, we will examine the way in which these various types of costs are allocated under a traditional cost accounting system.

Allocation of costs under classical cost accounting: Now that we have described the major categories of costs under a traditional cost accounting system, we are prepared to look at the way in which these costs are passed on to products and eventually to end users. As these cost accounting systems were developed around the turn of the century, allocation of costs in classical cost accounting tends to reflect the high costs of gathering data prior to the advent of modern information systems. A representation of the various costs, cost accounts, and allocation flows is shown in Figure 5.3.2.

As was previously mentioned, allocation of direct costs is straightforward since direct costs are simply attached to the product via the bill of materials. When a product is "costed-out" the bill of materials is used to roll-up the costs of components into the product cost, crediting and debiting appropriate accounts.

The allocation of costs starts to become less exact at the department expense level. In this indirect cost category, the various items contained in department expense are spread over products by means of an *allocation base* such as the number of units produced, or the value of the direct items contained in a product. Use of this first base could lead to such misallocations as non-painted parts bearing some of the cost of painting. Use of the second measure would result in such discrepancies as a pre-painted part being charged a higher portion of painting costs than a bare part since the pre-painted part would have a higher value than the bare part. However, compared to higher level indirect costs such as those included in general overhead, at least the department expense items may occur within a relatively small unit (the department) so that managers may be familiar enough with the process and costs to see past a faulty cost allocation. This is slim consolation given the complexity of production duties in many factories - in effect, proper understanding of costs is left to chance.

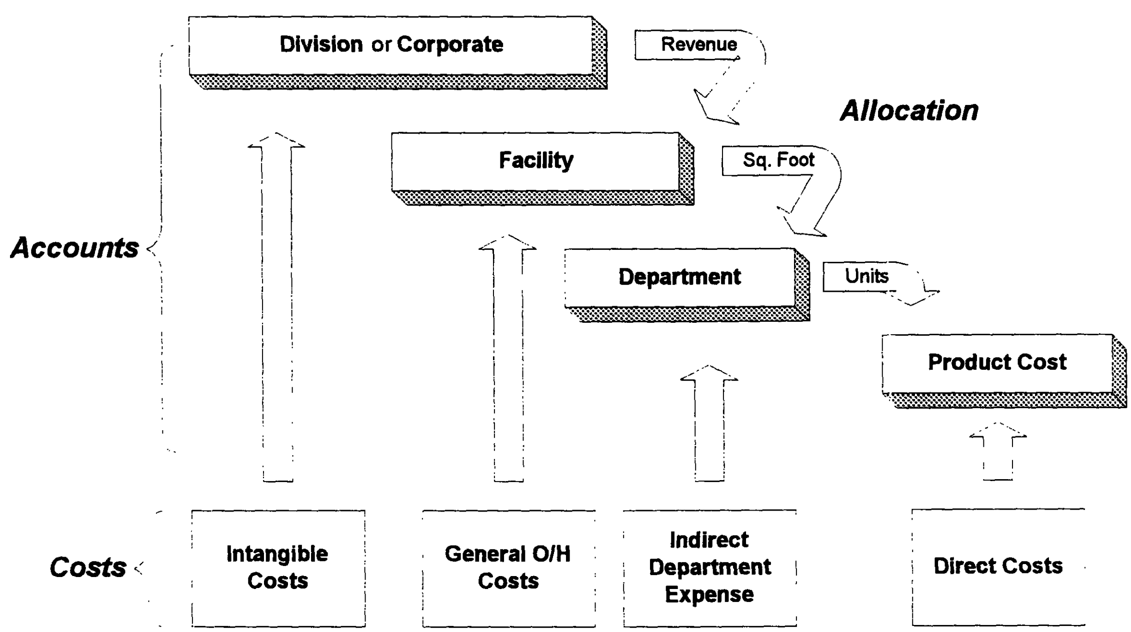

Figure 5.3.2. Overview of classical cost accounting in manufacturing

The next type of costs, the general overhead category, has even more potential to be overlooked in financial analysis. General overhead costs are brought together in various cost pools, and then spread over the production departments based on some type of factor such as the number of employees in a department or the square footage of that department. It is easy to see that the correlation between the number of employees or the square footage of a department and the amount of hazardous waste produced can be quite weak. In fact, some inverse relation might exist, as many polluting processes tend to be less labor intensive compared to assembly lines which produce relatively little pollution.

Common use of these two methods of allocation results in departments which generate very little hazardous waste such as assembly departments paying for the hazardous wastes of upstream coatings operations. Not only does the cost-causing department not bear its share of the cost, but it is likely that the department's managers don't even know the magnitude of those costs. In one of the facilities I examined, the manager of a department responsible for approximately 75% of the site's natural gas consumption had never seen an estimate of the fuel cost for his department. This cost was included in a plant fuel cost pool; the manager was not responsible for budgeting or control of this fuel and only an extraordinary effort on his part would allow him to even see the cost.

Finally, the various cost items which come under the title "intangibles" are least likely to be properly allocated under a traditional accounting system. Some of these costs, such as premiums for fire insurance, actually "show up on the books", albeit in the general overhead category where they are unlikely to be pulled out for economic analysis. Other intangibles, such as potential future liability from today's hazardous wastes, do not even show up in the companies cost accounting systems (or the financial accounting systems for that matter). These intangibles represent real potential costs, so they should be considered in the generation of operating plans and budgets. Since they are not included in the plan, the incursion of these costs results in "surprise" results, usually negative. Exclusion of this type of costs from planning means that they are not acted on until after a problem has occurred, when it is too late to do anything about them.

There are some ways to get around the problems that classical cost accounting brings to the evaluation of environmental improvements. Total Cost Assessments may be performed on a "snapshot" basis for process or product modifications. These assessments do not use the cost accounting data, but rather go directly to the sources of various costs and benefits for data, in effect bypassing the cost accounting system. The next section summarizes the results of a Total Cost Assessment for a proposed process change at the Otis Elevator Bloomington Plant.

5.4. TCA case study - conversion to powder coating at Otis

During the month of August, 1994 a Total Cost Assessment was performed on a proposal to switch the main paint line from solvent-based coating to powder coating at the Otis Elevator Bloomington Plant. It was thought that a thorough cost evaluation might turn up some hidden costs. Namely, it was hoped that a conversion to powder coating, which would virtually eliminate the largest single VOC source at the facility, would prove attractive due to a reduction in related operating costs and overhead expenses.

The cost accounting system in place at the plant was a traditional system following the model described in Section 5.3 with no link to any type of chemical tracking system. Due to this fact, little of the information needed to perform the Total Cost Assessment was available from plant accounting reports. Instead we relied on information from vendors, waste handlers, and interviews with Otis personnel to pull out the necessary data. A brief description of the scope and impact of this project is given below.

Project Scope and Impact: The paint line at the Otis plant is the location where the bulk of the surface coating is done. Steel doors, frames, and hundreds of smaller parts are conveyed through a cleaning and phosphating treatment for surface preparation, then dried and sent through two manual electrostatic paint booths where they are coated. After leaving the paint booths, items are conveyed through a large curing oven where the enamel coatings cure.

The largest capital item for a powder paint conversion would be the purchase and installation of two new powder paint booths, which are substantially different from the existing solvent based booths.* Since powder coatings are sensitive to humidity and heat, a structure with a controlled environment enclosing the powder booths would also be required. Custom colors would still need to be applied to some items, so a new low-VOC water-based booth would be installed. Finally, money was allocated to new fixturing and other necessary modifications for the conveyor system as well as for the removal of the existing paint booths. Conversion of the existing paint line from solvent-based to powder coating would require an estimated total capital investment of $821,000. The capital investment is detailed in Table 5.4.1.

The main impact of this project would be to substantially reduce emissions from the facility. The current coatings contain pigments, binders, and four to six pounds per gallon of volatile organic compounds (VOC's), 100% of which is released to the atmosphere.

---

* The existing paint booths are manual and have a thin-film scrubber on the exhaust stream to capture particulate matter from overspray. The proposed powder booths would be in two parts with an automated "cloud zone" followed by a manual touch up space.

Cost Item	Estimated Cost (Installed basis)
2 new powder paint booths	$347,000
1 Controlled-environment structure	$212,000
1 Water-based booth for custom colors	$53,000
Fixturing and conveyor modification	$159,000
Removal of old equipment	$50,000
Total Installed Cost	**$821,000**

Table 5.4.1 Capital estimate for powder coating conversion

The potential replacement powder coatings are applied electrostatically, and cling to the transfer surface until reaching an oven. At this point the powder first fuses to provide a uniform film and then chemically cross-links to provide a hard, durable finish. Powder coatings, in contrast to solvent-based coatings, are virtually 100% pigment and solid binder and thus have minimal emissions of VOC's. Further, since the type of powder application considered for this project involved total recycle of overspray, the amount of particulates released to the atmosphere would also be minimal.* It was estimated that the replacement of solvent-based coatings with powder coatings would reduce VOC's emissions from the current 50 tons per year to approximately 3 tons per year. The reduction in HAP's would be proportional. (The estimated annual emissions of VOC's from the main paint line at Otis Bloomington is approximately 50 tons. The portion of these emissions which are designated *hazardous air pollutants* or HAP's under the Superfund Amendments and Re authorization Act is approximately 20 tons.)

Operating Cost Savings: The potential cost savings from the powder paint conversion come from several sources. Interestingly, none of the estimated cost savings come from the direct cost category. Table 5.4.2 gives a summary of the annual cost savings realizable from the powder paint conversion.

---

* Unlike a conventional paint application where the paint stream is aimed directly at a part, the powder paint is applied by sending parts through a chamber which contains a cloud of electrostatcially charged paint particles. As individual particles settle out of the cloud they are conveyed from the floor of the chamber back into the powder supply bins from which they are recharged and sprayed back into the chamber.

As is seen from the table, the largest single contributor to the annual cost savings would be the savings in materials. This material savings figure represents the two-fold utilization advantage of powder coatings. First, since powder overspray is recycled, the effective transfer efficiency of the powder approaches 100%. (The current solvent-based coatings with electrostatic application yield transfer efficiencies of approximately 50%.) Secondly, since the solvent-based coatings are over 50% solvent, over half of the total weight of the coatings simply "goes out the stack" as pollutant. The savings in indirect labor were attributable to the elimination of the costly clean up of paint sludge from the water-scrubbers in the present booths.

Cost Category / Cost Item	**Annual Savings**
Department Expense	
Labor	$9,000
Materials	$98,000
General O/H	
Waste mgt.	$30,000
Utilities	$28,000
Reg. compliance	$18,000
Intangibles	
Insurance	$11,000
Future liab. for Haz. Waste	$11,000
Total Annual Cost Savings:	**$205,000**

Table 5.4.2. Annual Savings from Powder Paint Conversion Project

Several types of costs were pulled out of the general overhead category, including waste management, utilities, and regulatory compliance. The waste management costs included both internal handling costs and external transportation and disposal as well as a portion of the EH&S management budget which was attributed to the time necessary to handle waste related activities. Use of powder paint would reduce the generation of solvent and thinner wastes as well as paint sludge and paint booth water from the existing scrubber systems. Significant utility savings were calculated, largely from the reduction in heat loss to the atmosphere during winter months. (The exhaust streams from the existing paint booths dump hot air into the atmosphere in the winter while make-up air must be heated to allow satisfactory application performance.) The last type of cost savings pulled out of the general overhead category was regulatory compliance costs. It was estimated that without the contribution of this single large polluter, several "thresholds" of compliance would not be crossed and the long term costs of compliance certification would decrease.

The estimation of costs in the intangible category was less straightforward than that for department expense and general overhead categories. The insurance cost savings from reduced storage and use of flammable materials were more or less guessed at since this cost was part of a large policy negotiated periodically by the corporate indemnity group. A conservative number of 12% reduction was used. (The storage and use of flammable materials at the plant would be cut in half by the project.) The still less tangible costs of potential future liabilities from hazardous waste disposal were estimated using a method described in detail in the next section.

The overall breakdown by cost category is shown in Figure 5.4. As was mentioned earlier, under the existing accounting system none of these cost savings would show up directly in a product "cost", since none of the cost savings were from the direct cost category. Instead, about half of the costs, those falling under the departmental expense category, would be allocated to products by an intra-departmental allocation scheme. The other half of the costs, those in general overhead or intangibles, would either be greatly diluted over the entire facility or ignored altogether.

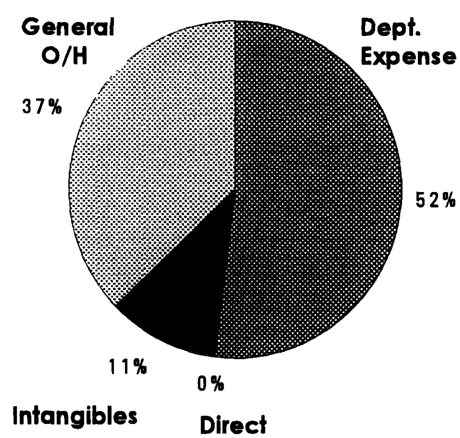

Figure 5.4. Breakdown of cost savings by category for powder paint conversion

Results and Implications for Economic Analysis: With an estimated capital outlay of \$821 k and operating cost savings of \$205 k per year, the powder project was determined to be economically favorable with a net present value of \$212 k and an internal rate of return of 18%. In addition to providing support for a project which can increase the overall profitability of Otis' Bloomington operation, the TCA study highlighted some of the pitfalls of the traditional cost accounting system which had not been providing information to managers about these potential savings.

In analyzing the cost savings for this type of project, the issue of allocation of average rather than marginal costs becomes important. For instance, one might argue that since the Otis Bloomington Plant must file for a site operating permit whether or not the paint line is converted to powder coatings, the cost of this type of regulatory compliance is not affected by pollution prevention. The influence of this point of view would be to withhold any type of compliance cost savings from projects unless all pollution sources were simultaneously eliminated. However, over a longer term time horizon, those average costs in effect become marginal costs. For example, as regulations evolve and new requirements emerge, it is likely that each pollution prevention project will allow some reduction in compliance costs relative to what they might otherwise have been. The longer term, dynamic view would support the argument that average cost savings should be applied in evaluating this type of cost savings.

Of the cost savings uncovered in the study of the Otis paint line, the vast majority were true marginal cost savings. For example, cost savings from materials and direct labor would be immediately realized: materials because they are purchased on an as-needed basis, and direct labor because the plant is currently hiring new workers and scheduling many workers on overtime. In the general overhead category, savings in waste handling and utilities would be pure marginal cost savings and would be immediately realized.* The timing of savings attributable to a reduction in regulatory compliance are more difficult to predict. Some of these costs would be true marginal costs, such as the costs of stack testing or permitting for specific equipment. Others would be part of overall items such as the cost of filing for Clean Air Act - Title V Permits. We elected to include these average costs in the evaluation according to the logic presented in the preceding paragraph. The distinction between average and marginal costs for intangibles is discussed further in the next section.

---

* As most of the cost of waste handling involved fees paid to treatment facilities or the wages of on-site contract laborers, immediate cost savings would result from a reduction in the amount of waste produced.

5.5. *Estimation of the future liability of today's hazardous waste*

As was mentioned in the introductory paragraphs to this chapter, one of the major objectives of a Total Cost Assessment is to bring out some intangible costs that might otherwise be neglected. One type of intangible, the potential future liability for releases of hazardous waste at an external treatment, storage, and disposal facility, was evaluated using a method developed at General Electric. (General Electric Corporate Environmental Programs, 1987) In addition to the study at Otis, a Total Cost Assessment was used to examine a pollution prevention project at Sikorsky Aircraft's Stratford, Connecticut facility. In both of these studies, an effort was made to extend TCA to account for potential liabilities from the disposal of hazardous waste using the GE method. This section will present a treatment of the estimation of future liabilities from waste disposal using this method and will provide a discussion of the application of such a method in industry. Since the cost of liability for hazardous waste releases is often seen in hindsight to be sizable, this section will try to discover the barriers to accounting *a priori* for these liabilities.

5.5.1. Purpose and summary of General Electric method

In an effort to put a price on the costs of the potential liabilities posed by releases of wastes of hazardous materials, the General Electric Company developed a worksheet for use by its various operating units. The General Electric method is a very simple one which uses information about the specific treatment, storage or disposal facility (TSDF) as well as the technology employed to predict future costs of possible releases to groundwater of toxic or hazardous materials.

There are three main components of the liability estimation: 1) a *TSDF-specific risk rating* containing information about the likely scope and probability of an incident, 2) a *technology factor* which takes account of the differing risks posed by various methods of treatment, storage, and disposal, and 3) a determination of the *cost of a major release to ground water of an "average" TSDF*. These three components of the liability estimation are described in more detail below.

TSDF-specific risk rating: The risk rating for a TSDF is determined by a combination of three factors under the General Electric method. The first factor, entitled "population" relates the TSDF's setting as either rural (low risk), industrial (medium risk), or urban (high risk).

The second factor, "proximity to water supply", also groups risk into three categories. These categories are broken out as follows:

- High risk - for a well less than one mile away or a ground water table less than ten feet down.
- Medium risk - for a well between one and ten miles away or a ground water table between 10 and 50 feet down.
- Low risk - for a well more than ten miles away or a ground water table more than 50 feet down.

The third factor which enters into the TSDF-specific risk rating, history of leaks, relates to the probability that an incident will occur based on the TSDF's past record in this regard. Again this factor was broken down into three categories; these are listed below:

- High risk - if the TSDF has had a leak, spill, or discharge that has harmed human health and/or the environment.
- Medium risk - if the TSDF has had a leak, spill, or discharge that has not harmed human health and/or the environment and for any potential leak, spill, or discharge.
- Low risk - if the TSDF has had no leak, spill, or discharge.

Once the value of each of these factors has been determined for the TSDF in question, an overall risk rating is given to the TSDF.

Technology factor: The second step in the GE method involves a technology factor which takes account of the differing risks posed by various methods of treatment, storage, and disposal, and is applied to the overall risk rating for the TSDF. A list of the values of this factor for 23 different TSD options was included in the General Electric workbook. No specific justification for the individual values of the technology factors are provided in the GE workbook. The engineers who developed the GE method appeared to view this factor as a means of rewarding "safe" technologies and punishing "risky" ones. For example, the TSD method which GE viewed as most likely to create future liabilities, deep-well injection, received a factor of 2.0. The technology viewed as least likely to contribute to future liabilities, on-site incineration, received a factor of only 0.01. Thus, deep-well injection of a waste stream would be allotted a 200 times greater potential for future liability than would on-site incineration of that same stream.

Cost of release from "average" TSDF: The third component of the GE method for estimating the future liability from the release of hazardous waste from a TSDF is the cost of a release from an "average" TSDF. In fact, this number is not something which has to be calculated for each case, but rather is a single number which is presented in the GE workbook. The "average" TSDF was considered to be a hazardous waste landfill conforming to the requirements of Part 264 of RCRA with a capacity of 143,000 tons of waste. The release was assumed to be the result of a catastrophic failure of the landfill liner, and the cost of release due to required corrective actions and legal claims was estimated at approximately $50 million. The items included in this estimate along with projected values are listed in Table 5.5.1.

Surface sealing	$2.5 MM	Real property claims	$1.6 MM
Fluid removal and treatment	$5.8 MM	Economic losses	$3.3 MM
Personal injury	$36.8 MM	Natural resource damage claims	$0.7 MM

Table 5.5.1 Costs of corrective actions and claims for "average" TSDF release

The "average" cost of a release is divided by the capacity of the landfill to give a per ton cost of $354. This value is then applied to the technology-corrected overall risk rating to obtain the per ton future liability estimate. This extra cost could be reckoned as the cost of providing indemnification for the company against future liabilities from releases of hazardous wastes.

5.5.2. Results for Otis and Sikorsky TCA studies

In July and August of this 1994, a TCA study was performed at Otis' Bloomington, Indiana production facility on the benefits of switching the main paint line from high-solvent paint to powder coating. The report prepared in August found the powder project to be favorable economically with a net present value of $212 k and an internal rate of return of 17% on an investment of $821 k. Afterwards the GE liability estimation method was employed on the various waste streams affected by this project and the project economics were updated. A listing of these waste streams with the effect of the liability model on the *total* cost of disposal is presented in Table 5.5.2. Inclusion of the liability estimate resulted in increases in disposal costs of 8% to 43%. The effect on the powder paint project was additional annual savings of $11k and an increase in the internal rate of return from 17% to 18%.

	Paint Booth Water	**Paint Sludge**	**Pre-treater Stage 1**	**Pre-treater Stages 2&3**	**Paint Thinner**
Method of Disposal	Chemical ppct. & Landfill	Landfill	Chemical ppct. & Landfill	Chemical ppct. & Landfill	Incineration
Nominal Disposal Cost ($/Ton)	$72	$726	$114	$142	$225
Future Liability / Ton	$31	$283	$31	$31	$18
Total Disposal Cost (Including Liability)	$103	$1,009	$145	$173	$243
% Increase in total cost	43%	39%	27%	22%	8%

Table 5.5.2. Estimation of waste liability premiums from General Electric Method

The TCA study performed at Sikorsky's Stratford plant examined the savings from switching to a new non-hazardous machine coolant at three machines in the sheet metal area. The GE analysis on the two waste streams involved in this project indicated a liability premium of 13% on the old "hazardous" coolant. The effect of this premium on overall project economics was negligible since labor costs were the dominant parameter in this project.

5.5.3. Issues and implications of liability estimation

The GE model is a relatively simple tool which can be used to estimate the expected value of future liabilities from wastes very quickly using only a few parameters which can be readily obtained from an environmental audit of the TSDF. However, the model is only capable of providing estimates in the broadest sense - the alternative of ignoring these potential costs must not be better. In deciding to use the General Electric method to examine future liabilities of wastes, part of our thinking was that although the tool is somewhat simplistic, it does represent an effort at quantifying a real risk. In fact, it may be the method's relative simplicity which would allow it to be utilized in a variety of plant settings. Three of the most troublesome areas for the GE liability estimation are described below.

Reliance on simplifying assumptions: The GE model relies on only three pieces of data specific to the TSDF in question: population of the surrounding area, proximity to a water supply, and history of leaks. This compares to EPA's PA-Score model which has 25 pages of data on the TSDF (U.S. E.P.A., 1991) and the AlliedSignal-developed ELSM model which uses about 40 pages of data to rate potential risks of various TSDF's. (AlliedSignal Corporation, 1987) The PA-Score and ELSM models both consider ground water contamination as well as surface water contamination, air releases and soil exposure. The ELSM model also rates the risk of fires, explosions, and spills. However, neither of these two widely-used models attempt to quantify the risk in monetary terms as the GE model does.

Time-frame for considering marginal costs: One issue which presents itself in the application of premiums to waste streams is what time frame should be used for the determination of marginal costs. For instance, I interviewed one manager at a large chemical company which disposes of a large toxic waste stream by deep-well injection, a controversial disposal method which involves "permanent" storage in a geological formation. In this manager's opinion, a tool such as the GE method would not be applicable for evaluating his waste stream because "the damage is already done". According to his reasoning, since this waste stream has been pumped into the ground for ten years, stopping the injections now would have no effect on the potential for future releases. Also he assumes that "a release is a release"; that the cost of a release is not proportional to the amount of waste in the hole. Given these assumptions, the marginal liability cost of continuation of deep-well injection is zero.

In my opinion, this type of short-term marginal cost perspective is prone to error. Certainly over a longer time horizon, the marginal cost consideration will encompass the total cost. For instance, as one injection site fills up and a new one is started, the marginal cost of future liability would equal the total cost of future liability. Perhaps more important than this consideration is the effect of continued practice on the size of a potential liability award. Under the GE method, the largest single contributor to liability cost is personal injury awards. It is reasonable to think that an attitude of "once we've polluted a hole, we might as well fill it up" could be effectively shown to a judge or jury by a claimant, increasing the possibility of a mammoth award. This argument strengthens the case for including the liability premium as a marginal cost, even when a "new" disposal site is not involved.

Estimation of discount factors and time horizons: The value of a reduction in liability for a future cost is strongly effected by the time at which that liability is expected to be incurred as well as the discount factor used to account for the time-value of money. The GE liability estimation workbook has a section for estimating the time horizon for a potential release, but makes no effort to discount the cost of a future liabilities over this time horizon. Arriving at such a discount factor would be very difficult, especially since the largest single contributor to the liability costs are personal injury claims. (i.e. The rate of escalation versus the relative market risk of these types of claims is highly uncertain.) Thus, for the time being no provision is made for discounting the future costs; in effect the inflation rate for these costs is equated to their opportunity cost.

Effect of financial health of the TSDF: The GE tool does not use the financial health of the TSDF as a parameter. This runs counter to the conventional wisdom that a TSDF in financial difficulty is both more likely to cut corners to reduce costs, and less likely to be able to pay for any potential incidents. This second factor could leave the manufacturer with the tab for remediation under a "deepest pockets" scenario.

5.5.4. Recommendations for Estimation of Waste Liabilities

The GE method is a tool which can be readily employed by engineers without the need for extensive training or a background in environmental science. Despite the above-noted issues with the model it does provide an improvement over the current practice of ignoring future liabilities of waste disposal.

In addition, other avenues for incorporating these liability costs into daily practice could be pursued. One possibility would be to incorporate indemnification into the handling of hazardous wastes. Van Waters & Rogers, Inc.'s ChemCare® has been advertised as a TSDF which provides indemnification for all future liabilities as well handling a companies hazardous waste disposal. This type of arrangement would replace the *de facto* self-insurance which now exists at most companies, for a price which would reflect the insurer's estimate of future liabilities. More financial study would be required on this solution to determine whether an efficient market exists for this type of indemnification.

Finally, it should be noted that the importance of including these future liability estimates in financial analysis will vary from project to project. For projects where the principal outcome is a reduction in generation of hazardous wastes, the liability costs will be more significant. On the other hand, a project which focuses on elimination of air emissions or reduction in labor is not as likely to provide significant savings in potential liabilities from hazardous waste disposal.

5.6. The role of cost accounting systems in incenting pollution prevention

After examining the weaknesses of traditional accounting systems with respect to allocation of environmental costs, it is useful to understand the role that the accounting systems play in motivating improvements at the plant and department level. Proper cost accounting should provide accurate information to managers whose job it is to produce high quality product with the lowest possible costs. An understanding of the sources of costs leads to a focus on reducing these costs at the source, given appropriate incentives are in place to motivate managers. Figure 5.6 gives a causal loop diagram for this system of performance, focus, and evaluation.

Starting at the top of Figure 5.6, we see how the risks of being a high cost producer of an item and negative effects on one's reputation of having "out of control" costs can motivate the manager to an increased level of pollution prevention effort. This commitment can lead to elimination of some wastes through modification of wasteful procedures and attention to detail in materials handling. Also, a high level of pollution prevention commitment may lead the line manager to pursue capital improvement projects which result in environmental improvements. The result of these efforts should be a reduction in the quantity of waste generated and hence a reduction in the cost of this waste, both in the cost of handling and disposal of the waste, and in the cost of the raw materials which are wasted. The cycle is completed with the improvement of departmental performance and the transformation of the department into a lower cost producer.

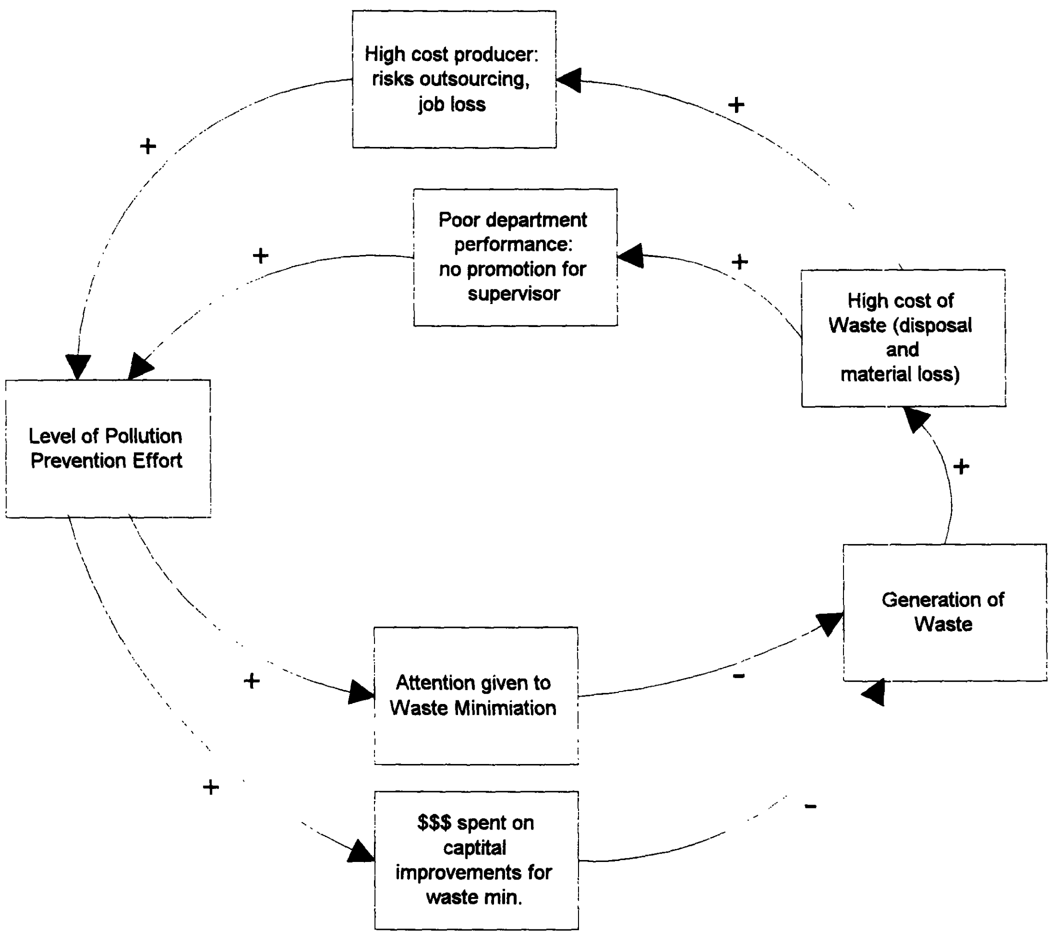

Figure 5.6. Causal loop diagram - role of cost accounting in pollution prevention

The overall result of antiquated cost accounting methodology and a lack of chemical tracking, especially with regard to processes and products with significant environmental impacts, is an estimate of costs that is grossly inaccurate. Managers are not able to look at their monthly reports and effectively target the most costly processes for improvement. Since the processes which pollute the most do not bear a proportionate burden for this pollution, incentives to improve are not localized. Referring again to Figure 5.3.2, the critical links between the high cost of the wasteful process and the department metrics are diluted or completely eliminated. This certainly doesn't mean that the costs go away, only they are spread across other departments which may have no appreciable contribution to these costs. When a plant is managed under this type of cost system, the "high cost producer" characteristic may be borne by all departments. In this case, management is likely to introduce *across the board* cuts in both capital and operating budgets. As might be guessed, this only serves to reduce the likelihood of environmental projects being undertaken.

The only way to fundamentally improve the ability of managers to identify improvement projects and to perform economic evaluations of these projects is to change the cost accounting systems. Activity Based Costing and use of "Charge-backs" are possible long-term improvements which can enhance the ability of managers to identify and justify cost-effective pollution prevention projects. These tools are discussed in the next section. In effective management of any organization, it is necessary to align incentives with desired outcomes. As is indicated by this discussion of the role of cost accounting systems in incenting environmental improvements, environmental management is no exception.

5.7. Incorporating TCA into daily practice with activity based costing and "charge-backs"

At the beginning of this chapter, the role of cost accounting systems in providing information for strategic and tactical decision making was described and an argument was made as to why traditional cost accounting systems fall short in bringing out economic incentives for implementing pollution prevention projects. The TCA study described in previous sections provided an example of a "manual" effort whereby a faulty cost accounting system was bypassed in order to uncover the true economics of a project. Referring to Figure 5.2, the Otis paint line case was a one time "snapshot" which provided economic information despite the unavailability of good data from the plant's accounting system by going around the system. In this section, two different approaches to improving the data provided by a cost accounting system are described. The first, activity based costing or *ABC*, involves a radical redesign of a plant's cost accounting system and involves all areas of a manufacturing organization. The second, the use of "charge-backs", involves incremental changes to an existing accounting system to improve allocation of environmental costs.

5.7.1. Activity based costing and Total Cost Assessment

As would be expected, the problems with traditional cost accounting noted in the previous sections are not limited to environmental costs, but are general problems of allocating costs to products. During the late 1980s, managers and accountants alike became discontented with traditional cost accounting systems and they began to turn to *activity based costing* systems. These systems focus on activities as the fundamental sources of costs and they use these activity costs as building blocks in compiling the costs of products. (Horngren and Foster, 1991)

Under an activity based costing system, large indirect cost pools are divided into smaller activity *cost pools* - one for each activity*. The pools are then allocated to specific outputs using activity *cost drivers*. For instance, a department painting doors might handle several kinds of work. Suppose all doors receive a primer coat, but three options are possible after priming: 1) the door is shipped immediately (and will receive a color coating from the construction contractor), 2) the door is painted white (the standard door color), or 3) the door is painted a custom color specified by the customer. Under an activity based costing system there would be at least four activity cost pools for this department: *door priming*, *standard door painting*, *custom door painting*, and *door shipping*.

The *cost driver* for an activity links the activity to a product. For instance, a white door would drive costs for *door priming*, *standard door painting*, and *door shipping*, but it would not drive costs for *custom door painting*. A custom color door, on the other hand, would drive costs for *door priming*, *custom door painting*, and *door shipping*. The custom door painting activity might generate a large amount of solvent waste due to frequent purges and might in turn serve as a cost driver for another activity: *solvent waste handling and disposal*. Use of activity based costing in this case would allocate the costs of extra clean up and disposal related to custom painting *only* to those products which required custom painting.

---

* A cost pool is something in the accounting system which shows a cost. For example, in a traditional accounting system *Department 400 Coatings and Solvents* would be a cost object which would receive all costs for purchases of coatings and solvents for Department 400. Under activity based costing, a cost object might be *Department 400 - Painting Doors* which would receive charges for coatings and solvents for doors as well as some labor and equipment costs for the door painting operation.

By allocating cost pools only to products or activities which actually impact the component costs, activity based costing can provide a much more accurate picture of true product costs. For this reason, activity based costing is a large step towards accurate assessment of environmental costs. Further, by providing a mechanism for timely reassessment of true product costs (i.e. via the annual operational budgeting process), activity based costing provides continuous incentives to reduce environmental impacts, at least those which have a significant costs associated with them.

5.7.2. Issues in the use of activity based costing for environmental cost assessments

Fundamental to the design of management accounting systems is the principal that the value of data provided must be balanced with the costs of obtaining that data. If data costs were not a issue, all costs would be directly allocated to products. Even with the advanced information systems which have made activity based costing possible, there are still inherent costs in obtaining (and analyzing) data. These transaction costs can discourage full costing of environmental expenses in some cases. For instance, when a waste stream is generated in several departments of a manufacturing facility and collected at a central location, there may not be an reliable way to determine how much waste came from each department. In this case, activity based costing in each department may help to accurately allocate the assessed waste charge over the products produced in that department, but the aggregate allocation to departments may not be very precise. In this case, it will take more than a switch to activity based costing to optimize cost allocation; depending on the information cost/benefit balance, an improved method of waste tracking might be justified. (i.e. a waste handling clerk who weighs drums as they are brought in, or a number of flow meters on continuous waste streams) Also, activity based costing may fall short on allocation of costs which are incurred at the plantwide level unless proper attention is paid to examining how the activities of managers and staff groups relate to the various products produced.

A shortcoming of traditional cost accounting systems which is shared by activity based costing is the failure to account for intangibles. Here again a special effort will be necessary to properly account for this type of costs and to make sure that product costs and prices reflect these intangibles.

5.7.3. Use of "charge-backs" to improve allocation of environmental costs

Although some companies and facilities have switched or are considering switching to an activity based costing system, most plants in America are still running under some form of traditional accounting system*. The recreating of an entire management accounting system is a monumentous task for a plant and can take several years to complete. For the manager who is at a plant which operates under a traditional accounting system with no plans to switch to ABC, another form of allocation of environmental costs called a "charge-back" is available.

The concept of a charge-back is simple. The cost of a general overhead item, such as the disposal of a hazardous waste stream, is taken out of general overhead and charged against a specific department or departments responsible for that waste. The use of charge-backs for hazardous waste disposal and handling has recently been started at the Hamilton Standard division of United Technologies. Although it is too early to tell what the effects of charge-backs will be at Hamilton Standard, it is certain that by taking costs out of general overhead and placing them at the department level, at least one layer of confusion is eliminated. This allows the managers that are closest to products and processes which generate wastes to feel the cost of those wastes directly. However, the charge-back method still falls short of the end goal of attaching the costs to an output (i.e. a product), rather than simply to a department.

5.8. Conclusions for environmental economics and manufacturing

Once we have recognized the need for a common language between management of the business and environmental management, we can proceed with discovering the best techniques and systems to ensure that environmental costs are properly included in economic analysis.

Traditional cost accounting systems do a poor job of linking indirect costs, including environmental costs, to products and processes. These accounting systems leave the majority of environmental costs in overhead accounts such as department expenses or general plant overhead where they are somewhat arbitrarily spread over the costs of

---

* A recent informal poll of managers from the divisions of United Technologies showed that only isolated use of ABC is occuring - and this is exclusively at commercial divisions. The defence related divisions cited government procurement specifications as an obstacle to implementing ABC.

various outputs. Further, these traditional cost accounting systems were firmly in place in the majority of plants studied.

A Total Cost Assessment methodology, such as that proposed by White, et al, can help to bring out many environmental costs which might otherwise be omitted in an economic evaluation. A discrete TCA study alone however, provides only a "snapshot" view; if the “blanks” are not filled in on a regular and timely basis, environmental costs will only be represented in evaluations of special projects. A TCA basis is a bare minimum for proper project evaluation, and should be applied to all projects instead of only the projects which are “environmental” projects. (Logically, if the environmental costs of a product or process are “hidden” one must search them out for all evaluations, not just those which are determined *a priori* to be environmental projects.) Finally it should be stressed that Total Cost Assessment is not some environmental magic bullet, but rather it is simply the act of performing a thorough financial analysis. For the manufacturing firm, TCA could be seen as a part of environmental stewardship, but it is really just proper financial analysis - that which seeks to maximize the profitability and the value of the firm.

A newer type of cost accounting, activity based costing, can greatly improve the proper costing of products and processes by breaking large cost pools into activity centers and by directly linking costs of activities to the item which triggered the activity. ABC provides information on product costs which is both more accurate and up-to-date than that provided by traditional accounting systems. ABC is most effective at allocating the environment related costs which occur at the department level, but it can be used to allocate costs which occur at the plant-wide level. (i.e. the time that top management spends meeting with government officials on environment related business.) Significantly, an ABC system, properly configured, can provide data consistent with the TCA methodology on a continuous basis. However, any ABC system will likely be limited to handling the allocation of tangible costs - those for which payments must be made on a immediate basis; an activity based costing system will not likely be able to handle the assessment and allocation of intangible costs, and so the inclusion of this type of costs will continue to require special effort.

The use of “charge-backs” can effectively take costs out of general overhead accounts and push them down to the department level. Charge-backs are easily implemented under a traditional cost accounting system and can help to focus department managers’ attention on issues which might otherwise be lost in general overhead. Charge-backs fall short of being a complete solution because they do not allocate costs down to the product level.

For the environmental manager in a plant where a traditional accounting system is the only foreseeable system, application of a Total Cost Assessment methodology on capital projects and new products combined with selective use of charge-backs can lead to a tighter integration between business and environmental considerations. For the environmental manager in a plant where activity based costing has been or will be implemented, involvement with the set-up of activity centers and the structure of the accounts can yield a cost accounting system which, with the exception of certain intangibles, provides accurate and timely data on true costs of products. This should help to align the firm's incentives with environmental and pollution prevention objectives.

Perhaps the single issue which is most important in bridging the gap between financial management and environmental management is the need for environmental managers to recognize the importance of rigorous financial analysis. Advocates of pollution prevention projects should stop relying on broad generalizations like "being green pays" and "environmental improvements are a strategic investment", and start selling their projects with the financial analysis which otherwise may be used against them.

6. Conclusions on Integration of Environmental Management

This chapter begins with a section describing some of the accomplishments of the work at United Technologies. It became obvious during the course of study that there are a number of forces which oppose the successful implementation of chemical tracking and full cost accounting, despite the motivations for pursuing these programs. The main purpose of this chapter is to discuss these opposing forces with an eye towards enabling the implementation process.

There are numerous attributes which set apart the environmental management challenges at a plant like United Technologies Otis Elevator plant in Bloomington, Indiana from a chemical plant or refinery. In this chapter we will consider attributes of environmental management at this type of facility that affect environmental performance in general, and specific organizational barriers to implementation of tracking and full cost accounting. The last section provides a picture of the outlook for environmental management at the plant level in view of its current state and past progress. Specific suggestions are made as to how plant personnel might overcome obstacles to better environmental management. It is hoped that a thorough description of these obstacles might also help to sensitize the general manager to the degree of support needed for environmental improvement.

Finally, it should be noted that many of the conclusions reached in this chapter are pulled from my discussions with environmental professionals outside of United Technologies; although the implementation process was not always easy, we *were* able to make substantial progress at Otis. Therefore these observations on the barriers to environmental improvement are not a judgment on United Technologies or Otis Elevator, the people which have encouraged this important work, but rather are descriptive of issues facing the discrete manufacturing industry in general.

6.1. Accomplishments at United Technologies Otis Elevator

By the end of December, 1994, a systematic tracking of chemical purchases and receipts was up and running at Otis Bloomington on the plant's computer integrated manufacturing system. This set-up will enable the collection of aggregate data for chemical usage at the plant to be done in a fraction of the time required by the old manual method. The use of the plant's manufacturing system rather than the installation of a dedicated environmental system shows the economies of scope which can be achieved by focusing on coordination across functions and use of existing resources. A method of obtaining process specific emissions data using log sheets and a computer spreadsheet was implemented. This method allows the plant to collect emissions data on a continuous basis as will become necessary later this year under the Clean Air Act Amendments of 1990 Further, this method should allow sufficient flexibility such that a new system will not have to be created each time a new environmental law comes along. It is too early to determine exactly what effect the improved environmental data will have on Otis' pollution prevention effort, but it should allow for a more timely and accurate understanding of the plant's environmental performance.

On the financial incentives side, the Total Cost Assessment performed for the conversion of a solvent paint line to powder coating provides both an opportunity for Otis to take advantage of a substantial cost improvement as well as a lesson to other United Technologies Divisions about the value of this type of economic analysis. The words of a project manager from one of the UTC Aerospace divisions perhaps described this best: "In the past we did environmental projects because we had to. It was 'do this or we get fined' or 'do this to get through an emergency'. Today we've solved most of the more urgent environmental issues and so top management is starting to ask for more cost justification before we can proceed. If this [TCA] will help us demonstrate the value of our environmental projects, it is just what we need."

In Chapter 3 as well as throughout the thesis, a number of "external" motivators for environmental improvements were mentioned including high waste disposal costs, the need to comply with environmental regulations, the cost to product of low raw material conversion, potential future liabilities, and the cost of poor community or customer perceptions. It has been demonstrated that a full cost accounting system, one which brings out all relevant operating costs, including environmental costs, can help managers to consistently make decisions which will be economically favorable to the enterprise. Further, it has been proposed that the implementation of a comprehensive system for chemical tracking and emissions reporting is not only necessary to enable full cost accounting, but it can also justify itself financially by reducing the manpower needed to comply with government reporting requirements.

Despite the various motivations for plants to improve their environmental performance by implementing features such as a chemical tracking system and full cost accounting, there remains a great deal of progress to be made. As was mentioned earlier, the Otis plant was the first at United Technologies to develop a chemical tracking system which relied primarily on the production control system rather than being a system in and of itself. The other plants with a rigorous tracking of chemicals relied on systems and staffing which would not be affordable to the majority of business units. The accounting side of the picture was even less positive. In various inquiries I made both within and outside of United Technologies, I was unable to find a discrete manufacturing plant with a true full cost accounting system in place.

6.2. Issues hindering environmental improvement in discrete manufacturing

As was alluded to in the first chapter, there are a number of important differences between typical discrete manufacturing facilities and process-based plants. In this section, a number of these differences are discussed in as much as they affect the environmental improvement effort. Further, under each topic suggestions are made regarding how a discrete plant might overcome these hindrances.

Employees lack knowledge of chemicals. Typically in discrete manufacturing facilities there is a low degree of understanding of chemicals and their effects on humans and the environment. Most of the technically trained personnel have backgrounds in mechanical or industrial engineering, or perhaps electrical engineering or computer science. This differs from a process industry where many of the technical employees would have backgrounds in chemistry, chemical engineering, or a chemistry related field. As a result, the environmental manager at a discrete parts plant must spend a significant amount of time not only educating employees about the environmental impacts of operations, but also dispelling myths and rumors about chemicals and their uses.

The environmental manager or "engineer" himself is often someone with an education in safety, human resource management, or industrial engineering who is learning about environmental science "on the job". These factors do not necessarily lead to poor environmental management, but they do indicate that a level of understanding which might be taken for granted in the process industries cannot be assumed here. Ways for dealing with the low level of chemicals knowledge in discrete plants might include emphasizing a chemical or environmental background in hiring of "environmental engineers", or providing consultancy services for a number of plants from a central environmental group staffed with trained environmental professionals. This second alternative can be difficult to manage because technical staff personnel can tend to get isolated from the realities of plant life and thus the value of their contribution is diminished. However, staff groups can bring in technical solutions which would not likely originate at a plant.

Environmental concerns have low visibility and priority. Partly from the fact that chemicals are poorly understood and partly due to the presence of many other daily concerns, environmental management tends to have low visibility and a low priority in a discrete manufacturing facility. In small job-shops the custom nature of operations can make the measurement of environmental impacts very difficult and hence can lead to neglect of measurement altogether.

Chemical processes and environmental performance are seldom seen as core strategic interests at the plant level.* For example, the plant's customers might be willing to pay a little more for a new varnish if it would extend motor life. On the other hand, they would not likely be willing to pay more for a motor solely because it was made with a new varnish which reduces solvent emissions. As companies strive to meet customer needs, environmental concerns in manufacturing are bumped down on the priority list. Exceptions to this rule are found when a customer's own purchasing standards mandate the elimination of "harmful" raw materials in a supplier's process. An example of this is found in the case of legislation requiring products produced with CFC's to bear a CFC information label. As customers such as the auto producers did not want to send out vehicles laden with CFC labels to consumers, they forced suppliers to modify processes to eliminate the use of CFC's in their own processes.

Another strategy for increasing the priority and visibility of environmental issues at the plant level is to incorporate specific environmental incentives into the metrics which are used to judge the performance of plant management. At Otis, certain environmental goals were included as "key success factors" along with other operating parameters such as inventory turns, productivity, and quality. Performance to plan affected the view which corporate management held towards the plant and determined bonuses for top managers. When these types of performance measurements are planned, there is a vital need to

---

* In fact, although the value of chemical products consumed at a plant may be quite large, the value of discrete items such as metal stock or completed components is often one to two orders of magnitude greater.

ensure that the goals incorporated reflect the key environmental issues at the plant, and not just the ones which are easiest or least costly to attain.

Underestimation of work required. Over the past ten years, the amount of effort required to provide mandated plant environmental data has mushroomed. Consequently the demand on resources, both human and capital, for producing this data has also grown dramatically. During the course of this study it was observed that the costs of management of environmental data are often underestimated. Plant managers may tend to underestimate these costs for several reasons. The first reason is that environmental management costs are typically not strongly tied to production volume. For instance, during the early 1990's when plants were running at low capacities due to recession, reporting and compliance costs were steadily escalating. But environmental management budgets were often cut or held flat as part of a plant's across-the-board budget cuts. When this type of budgeting imbalance occurs, environmental data responsibilities may be neglected or handled slipshod.

Secondly, plant managers may underestimate environmental data costs when they lack familiarity with environmental affairs. Although some plant managers are active in working with government and public interest groups on various environmental issues, many plant managers avoid environmental issues entirely. They approach the environmental manager with an attitude of "I hired you to deal with this so that I won't have to." Subsequently, these managers are not aware of the increasing workload that their environmental managers are facing. As a result, some environmental managers are not given resources to adequately perform their duties.

This issue of inadequate allocation of resources will probably be worked out in several ways. As new managers "come up through the ranks" in today's atmosphere of increased attention to the environment, accepting responsibility for environmental stewardship will probably come more easily. Also, corporations will increasingly try to ensure that all divisions and facilities are meeting minimum environmental management standards as the costs of non-compliance and specific environmental incidents increase and threaten shareholder value.

6.3. Organizational barriers to plant implementation of tracking and TCA

Three main organizational barriers to implementation of efficient chemical tracking and improved environmental cost accounting were noted across a range of the facilities observed. These barriers include a lack of ownership of systems across functions, a shortage of multi-skilled professionals in various functions, and the strong inertia of traditional cost accounting systems. Each of the issues is discussed below:

Requirement for system ownership across functions. In any business process, the greatest potential for error or failure lies at the seams between the various functional groups involved. Chemical tracking is a process which has only an indirect impact on the business, but depends on the correct and timely input of almost as many functions as does production itself. Precisely because chemical tracking is not at the core of the business, there appears to be a sizable reluctance among various functional managers to take on real responsibility for its success.

For instance, an MIS manager might see his role as providing necessary data for planning and control of production. Responsibility for providing chemical purchase and usage data may be seen by MIS as an "environmental job". In fact in some instances the environmental staff might not want anyone else to handle "their data". The age old "that's not my job" attitudes or empire building motives are probably not inherently worse in environmental management than anywhere else. However, the need to cross many functional borders to obtain data which has not historically been important to the firm means that these forces can be very destructive to a tracking implementation. The only real solution to this problem is a clear and strong commitment from top management to the environmental tracking effort.

Need for multi-skilled professionals in functional groups involved. The generation of data on chemical emissions and waste requires a number of different types of tasks ranging from shop-floor record keeping to software manipulation to estimation of emissions factors from thermodynamic data. In addition to, and related to the unwillingness of various functional managers to accept ownership for chemical tracking is the shortage of managers and workers with skills outside of narrow functional definitions. For instance, some environmental engineers come to the job with primarily an industrial hygiene background and with little or no computer literacy or knowledge of emissions equations. Very few of the manufacturing engineers and virtually none of the information systems staff at the facilities examined had any background in environmental issues. I sat in on several "cross-functional" meetings where each of three or four managers put forward an action plan, while the others nodded agreement. None of the managers seemed to realize that other's plans contradicted their own and the various participants left feeling that everyone had agreed to their own concept of a plan. Such a meeting does not result in a consensus action plan that all will follow, but rather a disjointed effort which may actually be a step backward.

While the general issue of a lack of cross-functional expertise in manufacturing has been widely discussed in management literature during the last decade, the problem remains serious, at least in the case of the manufacturing/MIS/environmental arena. When companies are not able to generate solutions to their environmental data management problems in-house, they are often forced to go to outside consultants for data management systems at a very high price. If the problems persist, they are then blamed on the consultant. The underlying human issue of an unwillingness to jump out of a narrowly defined functional box persists.

In an effort to develop greater cross-functional expertise, companies have begun to place more emphasis on cross-functional assignments as part of the human resources development process. However, it was noted during interactions with many environmental professionals from different facilities that people are rarely rotated through environmental management as part of a cross-functional development program. One possible remedy to this specific lack of multi-skilled professionals would be to create cross-functional career paths which would include environmental management.

Inertia of traditional cost accounting systems. A very strong organizational barrier to the implementation of new cost accounting systems which would lead to a more proper assessment of environmental costs and increased incentives for environmental improvements is the inertia of traditional cost accounting systems. Although the benefits of new accounting systems such as activity based costing have been widely touted for over fifteen years, there has been a great reluctance to abandon the traditional accounting systems which were developed in the days of Frederick Taylor. At United Technologies I talked to several managers whose plants had plans to upgrade their internal cost accounting systems at some point in the future, but I was unable to find a single plant where a new system had actually been implemented.

Underlying the inertia of traditional cost accounting systems is doubtless some pure fear of change, but it also seems likely that the real switching costs of a conversion are substantial. A cost accounting system is something which all managers at a plant rely on for control and planning of their activities. The budgets from last year are used as a basis for this year's budgets. Territories (and sometimes empires) are defined by accounts in the cost accounting system. The implementation of a new accounting system causes a period of disorder while managers re calibrate themselves to the new rules. Further, in many plants the old cost accounting systems have expanded over time to the point that no one person at a plant really understands the whole system. It is thus difficult to find a point from where to start in bringing in a new system.

As the issue of problematic traditional accounting systems is of general importance in manufacturing management, they will probably not be uprooted solely because of environmental management incentives. Until the plant accounting systems are improved, methods such as periodic Total Cost Assessments and "charge backs" (discussed in Chapter 5) will need to be used to better incorporate environmental issues into decision making in the manufacturing environment.

6.4. Outlook for environmental management in discrete manufacturing

This researcher's initial impression of the overall state of environmental management in the discrete production facilities was somewhat negative. One the one hand it seemed as if environmental concerns were neglected in many plants, especially in regions where little regulatory enforcement had been present. On the other hand, some plants were very concerned with environmental issues and seemed to throw money at environmental management without really trying to incorporate it into the overall management of the business.

Despite the fact that much improvement is still necessary in plant environmental management, one should not overlook the progress which has been made in discrete manufacturing facilities over the past decade. Not so long ago, waste solvents were poured down sinks or placed outside in open drums to evaporate. Environmentally friendly options such as solventless powder coatings were not practical on a large scale as they are today, and many of the pollution abatement devices which are commonly found in plants today were not even on the drawing board. In any emerging field, there is an evolution from a crude state where only the most important features are developed, to a better understood and more efficient state where attention is given to integration with other fields and more attention is focused on operational efficiency. It is likely that the environmental management field is somewhere in the middle right now - still inefficient and non-integrated in some ways, but facing increasing pressure to improve its quality and to show its value.

Part of this evolution will entail a clearing of some of the fog which surrounds issues in environmental management. For instance, one can still find zealots who claim that "the environmentally friendly way is *always* the most economical way in the long run". However, the hard facts of the manufacturing environment suggest otherwise. Pollution abatement costs money. Environmental permitting and compliance reporting cost money. Neutralizing and precipitating a waste water stream instead of injecting it into the ground costs money. *Source reduction* is a prominent buzzword, but there exist viable products for which those *pollution-free* processes do not exist, at least for now. Many companies have fixed capital investments in polluting processes which cannot be converted to clean technologies without substantial new investment. These comments are meant to be somewhat of a reality check. Those who think that environmental management will be hotly pursued by companies "once they realize how much money they can save" are naive. Integration of environmental management into the business of manufacturing should be pursued because the need to manage environmental concerns is a fact of life. But there will remain a tension between environmental management and the pursuit of financial goals, because environmental management is not a primary source of profits nor of competitive advantage for the overwhelming majority of firms.

The best approach for companies to take towards environmental management will be one which recognizes the need for increased plant-level as well as corporate-level attention to environmental affairs and which brings the environmental function into the plants' decision making circles. At the same time, the environmental management function should begin to be judged by higher standards of quality and operational efficiency. The tension between environmental management as bothersome cost versus inherent responsibility will continue to work itself out well into the next century.

7. Suggestions for Further Research

During the preparation of this thesis and the work it leading up to it, a number of ideas were generated about further ways in which environmental management could be improved. In this brief chapter, several of these topics are introduced and suggestions are given for the work in these areas which might contribute to progress in environmental management.

7.1. Tracking and reporting system architecture

The pace of change in the use of information systems in manufacturing facilities is currently very fast and it is my belief that manufacturers, especially large integrated firms, could realize a significant benefit by focusing quality MIS resources on the optimization of environmental data processing. Areas to examine might be the use of relational databases for manufacturing and environmental data as well as the linkage of various plants and corporate offices into a single database to reduce the burden on environmental managers in plants (who currently spend a significant amount of time sending various reports to corporate staffers).

One evidence for the possibility of "low hanging fruit" in this realm is the presence of hundreds of small, often *fly-by-night* software companies offering various sorts of environmental tracking and reporting systems and data bases. My personal experience with several of these companies during the work at Otis attests to the fact that almost anyone who can even utter the words "computer" and "environmental" in the same sentence can make a living in this field. At least one company I contacted had already clued in to this potential; Digital Equipment Company was busy developing their own hardware and software systems for environmental management. As this is turning into quite a large business overall, it would be interesting for someone to take the time to examine the dynamics of the environmental software design and draw some conclusions about the best ways for companies to proceed on a corporate-wide basis.

7.2. Incorporation of TCA into an activity based costing implementation

In this paper the Total Cost Assessment (TCA) methodology was expounded upon and a TCA case study was provided as an illustration of TCA's potential for providing incentives for pollution prevention. However, although activity based costing (ABC) was described as having potential for providing these same incentives on more of an automatic basis, no specific case of an ABC implementation was found where environmental concerns were intentionally addressed. I think it would be very insightful to enlist an environmental professional in an ABC implementation team at a plant in order to see what the real benefits of such a system would be.

7.3. Cross-functional career paths including environmental management

As was mentioned in the last chapter, part of the gap between environmental management and general plant management stems from the fact that environmental managers tend to be somewhat isolated in terms of career progression compared to other managers. It was noted that although recent trends toward cross-functional expertise have resulted in movement of people between various functions (i.e. finance to manufacturing to marketing), the environmental professional is often locked into an environmental or environmental, health, & safety career progression.

It might be interesting to find examples of companies where environmental management is included on a general management career progression and then to compare the level of integration of their environmental management with the business as a whole. The results could be compared to those of companies where such cross-functional rotations are rare.

7.4. "Design For Environment" and manufacturing's environmental impact

Many industrial companies in the U.S. are currently involved in "Design For Environment" (DFE) initiatives in which environmental impacts of a product throughout its life cycle are considered in the design stage. As one of the main areas of environmental impact for many products is their manufacture, one would expect the effects of DFE to be seen in plants where DFE-designed products are made. For instance, as engineering specifications for new products dictated specific "clean" processes such as aqueous versus solvent degreasing or water-based versus solvent-based coatings, the older more polluting processes should slowly go away. As fewer and fewer parts require processing in the old equipment, manufacturing managers would eventually be motivated to remove the equipment in order to free up plant space and save on maintenance, thus eliminating the polluting processes even for products which do not explicitly require a "clean" process.

Although this scenario might logically flow from an emphasis on DFE, it would be interesting to examine plants where DFE-designed products are being produced to see if the reality is following the theory.

References:

AlliedSignal Corporation, *ELSM - Environmental Liability Scoring Model*, Morristown, New Jersey, 1987. (Internally developed model, shared within the *Waste Site Inspection Group* consortium.)

Dorfman, Mark H.,Warren R. Muir, and Catherine G. Miller, Environmental Dividends: Cutting More Chemical Wastes, INFORM Group, Washington, 1992.

General Electric Corporate Environmental Programs, Financial Analysis of Waste Management Alternatives (Rev 1, July 1987), Distributed by ICF Technologies, Fairfax, Virginia.

Hennessy, Claudette, *The Clean, Green Information Machine*, Chemtech (vol. 23 no.11), American Chemical Society, New York, November 1993.

Horngren, Charles T. and George Foster, Cost Accounting: A Managerial Emphasis, Seventh Edition, Prentice Hall, Englewood Cliffs, NJ, 1991

Johnson, H. Thomas and Robert S. Kaplan, Relevance Lost: The Rise and Fall of Management Accounting, Harvard Business School Press, Boston, 1987.

Esry, George T., *How to Automate Compliance Reporting*, Pollution Engineering (vol. 25 no. 9), Cahners Publishing, Des Plains, May 1, 1993.

Rich, Jerry, *Software Maze*, Pollution Engineering (vol. 26 no. 1), Cahners Publishing, Des Plains, January 1, 1994.

Sheridan, John H., *The Antipollution Maze: Getting Easier to Solve*, Industry Week, Volume 243 No.9, Penton Publishing, Cleveland, May 2, 1994.

United States Environmental Protection Agency, PA-Score Software: User's Manual and Tutorial, Washington, D.C., 1991.

White, Allen L., Monica Becker, and Deborah E. Savage, *Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention*, Pollution Prevention Review, Summer 1993