A METHODOLOGY FOR ASSESSING ENVIRONMENTAL PROJECTS

by
Natalia K. Falinski

B.S. Electrical Engineering
Clarkson University, 1989

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

Master of Science in Management
and
Master of Science in Civil and Environmental Engineering

at the
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ABSTRACT

With the emphasis placed today by government, environmental activists and individuals on environmental, health and safety issues, it has become almost imperative for manufacturing companies to integrate environmental, health and safety issues into their business decisions. Unfortunately, there is no single model that exists today to assist businesses in making these decisions.

The method outlined in this paper describes an evaluation process a company can use to ensure that environmental, health and safety issues are addressed in their decision-making process. The method addresses both the financial and qualitative factors that are necessary in making educated decisions. The goals of the method are to:

- Ensure that critical information is gathered before making a decision.
- Assess projects consistently that affect multiple sites.
- Ensure that all projects that are evaluated consider the same categories of information.
- Generate a summary report for a user to compare two or more projects.
- Create a consistent approach to assess multiple projects based on cost, implementation time, and net benefit to the environment.

The model focuses on projects in the semiconductor industry, but can be applied to other industries as well. It is based on a combination of research performed at Intel, SEMATECH, and academia. An application of the model and a recommended implementation strategy for its use are presented.

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This thesis is the result of extensive research at Intel Corporation in Albuquerque, NM; Phoenix, AZ; Santa Clara, CA; and Portland, OR in conjunction with the Leaders for Manufacturing Program at MIT.

I would like to thank the Intel Corporation for providing the opportunity and the resources to undertake this project. I would also like to gratefully acknowledge the Leaders for Manufacturing Program for its support of this work.

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I would also like to thank my thesis advisors, Professors Henry Jacoby, Duane Boning, and David Marks, for their inputs, feedback and guidance in completing this effort.

Finally, I would like to dedicate this thesis to those special people close to me. To my parents, for their continued love and support through all of my endeavors. To my sister, Nadia, who was always there to listen. Finally, and most importantly, to Chris, for his continued patience, love and support.

Bibliographical Note

Natalia Falinski graduated from Clarkson University in Potsdam, NY in 1989 with a Bachelor of Science degree in Electrical Engineering. Upon graduation, she worked in General Electric's Transportation and Aerospace Divisions as part of the Manufacturing Management Program (MMP). After completing the MMP program, she held positions in production control and program management at General Electric's Radar and Sonar Systems in Syracuse, NY. In 1995, Natalia joined the Leaders for Manufacturing Program at MIT and completed her research internship at Intel Corporation in Albuquerque, NM. After graduation, she plans to work for Hewlett-Packard's Corporate Procurement Division.

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1. Introduction

This thesis is the result of six months of work sponsored by Intel Corporation and the Leaders for Manufacturing Program at Massachusetts Institute of Technology. The Flash Technology Development organization located in Fab 7 in Rio Rancho, New Mexico was the primary Intel sponsor. This section describes the purpose of this thesis and provides an overview of the project.

1.1. Purpose

The purpose of this thesis is to address the issue of integrating environmental, health and safety (EHS) concerns into a company's decision-making process concerning investment projects. The investment projects being assessed are the ones that have an impact on the environment and/or the health and safety of a company's employees or outside community. These projects are typically at the site, fab[1], design, or manufacturing and operation level. Currently, there are no structured methods available that consider EHS impacts, qualitative impacts, *and* financial impacts. This thesis will describe the method developed at Intel to evaluate these projects. The method focuses primarily on projects associated with the semiconductor industry, but can be applied to other industries as well.

1.2. Project Overview

Recently, the emphasis on environmental, health and safety issues has increased. Numerous methods have been developed to address these issues. For example, a systematic approach called Design for the Environment (DfE), has been developed to help companies create environmentally friendly products. It treats recyclability, disassembly, maintainability, and reusability as design objectives to ensure that relevant environmental concerns are addressed during the product development phase. The method uses a proactive approach and emphasizes the development of products that *avoid* the creation of pollution.[2] Life cycle analysis (LCA) tools such as the Environmental Priority System, the Health Hazard Scoring system, and the Sustainable Process Index have also been developed to address the potential environmental impacts of products throughout their life cycles. These methods focus on determining the "greenness," or environmental soundness of products.[3]

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[1] A fab refers to the facility where semiconductors are fabricated.

[2] Allenby, B.R.. "Design for the Environment: A Tool Whose Time has Come," SSA Journal, September 5-9, 1991.

[3] Hertwich, E.G., et al. "Evaluating the Environmental Impact of Products and Production Processes - A Comparison of Six Methods," Combined Research Reports. University of California Berkeley, ESRC. 1996.

These methods are appropriate in determining specific impacts to the environment, health and safety. However, they do not provide an overall process that companies can use to analyze the feasibility of implementing a project that may impact the environment, employee health and safety. An evaluation method would need to specify the factors that should be considered and how these factors should be prioritized. The method would also need to account for the costs and the criteria that should be used to compare two or more projects.

A thorough analysis of EHS issues early on in a decision-making process is becoming increasingly critical. If an analysis is made without considering EHS issues, there is a high probability that future modifications will be required. If critical information is missing from an analysis, the calculated costs could potentially be under or over-estimated. Employees could be put at risk, the surrounding environment could be affected, and certain regulations could be violated. These changes, miscalculations and misinformation can delay design releases, interrupt product throughput, delay production schedules and increase the risk of fines. This threat is extremely critical in the semiconductor industry. Semiconductors typically demand high prices, but have fairly short product life cycles. Therefore, any delays in production can result in a large loss in revenue for a semiconductor manufacturer.

The intent of this thesis is to provide an evaluation method that will capture the relevant data required to make timely decisions on investment projects. The goals of the evaluation method are to:

- Assist a business in making educated decisions about projects that impact the environment and health and safety.
- Ensure that critical information is gathered before making a decision.
- Provide a consistent method to assess projects that will impact multiple sites or multiple business units within a single site.
- Ensure that all the projects being assessed consider the same categories of information.
- Generate a summary report of the information and assessment results.
- Assign a relative rank to the projects so a user can compare and decide between two or more projects.
- Create a consistent approach to assess multiple projects based on cost, implementation time, and net benefit to the environment.

1.3. Definition of Projects Being Evaluated

The intent of the method is to evaluate proposed investment projects that have the potential of impacting the environment, the health and safety of employees or the health and safety of the surrounding community. Examples of this type of investment projects include:

- Changes to existing processes or equipment that negatively or positively impact waste streams or the health and safety of individuals.
- New processes or equipment that introduce a different waste stream, increase/decrease a waste stream, or increase/decrease the health and safety risk to individuals internal or external from a site

Processes and equipment refer to what is used either in the *direct* manufacturing of a product or in *support* of manufacturing a product.

In *direct* manufacturing, the types of projects that would be evaluated are part of the actual processes of making a product. These projects include:

- Changes made to chemicals used in a process.
- Introducing new chemicals to be used in a process.
- Changes made to current environment control systems used within a process.
- Introducing new environment control systems to be used in a process.

In *support/indirect* manufacturing, the types of projects that would be evaluated do not have an impact on the processes directly, but rather support the operations required to run a facility. These projects are similar to the aforementioned projects, but do not directly impact manufacturing.

Henceforth, all references to the type of investment projects or changes mentioned above will be referred to as the "*project.*"

1.4. Future Benefits of the Evaluation Method

Not only will this method provide a structure and the tools necessary to evaluate projects, it will also provide future benefits for a company. If successfully implemented, the use of this method will:

- Generate an awareness, at all levels of the company, of the importance of both the financial and the qualitative issues associated with making decisions on projects concerning EHS.

- Create a better understanding within the manufacturing and finance organizations of the benefits of using a combination of Activity-Based Costing and Life Cycle Analysis.[4]
- Provide a structured framework to follow that will help to improve the evaluation and decision-making process for investment projects.
- Develop a consistent approach for ranking projects across business units.

[4] Based on a philosophy developed by a joint research project involving Oregon State University, Wright, Williams & Kelly, and SEMATECH.

2. Impact of Environment, Health and Safety (EHS)

Over the years, dozens of environmental, health and safety regulations have been passed with the majority issued within the last two decades. Figure 2-1 shows the cumulative number of U.S. environmental regulations since 1895[5]. These regulations have increased industry and company environmental responsibility. Businesses are becoming more concerned with the potential fines associated with non-compliance to these regulations and how these fines can have an impact on corporate profitability, cost of capital, and stock prices.

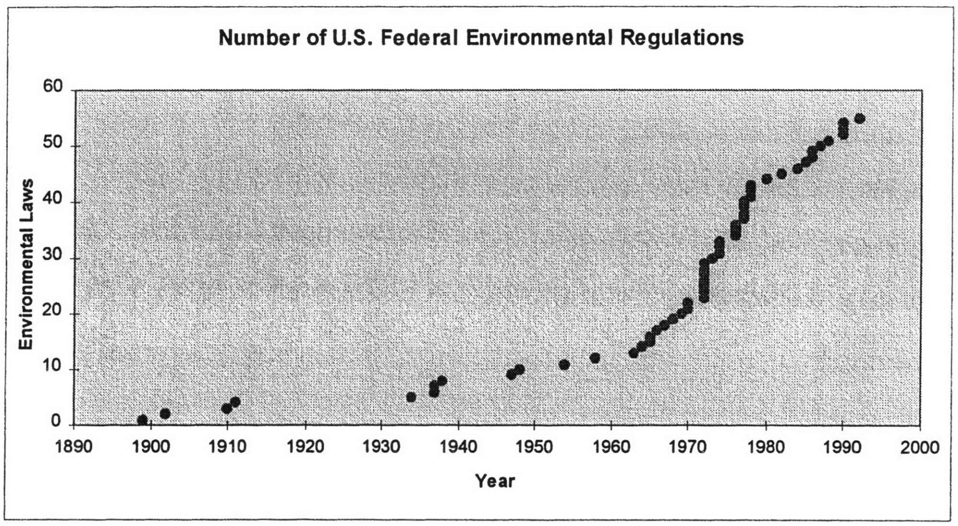

Figure 2-1 U.S. Environmental Legislation

An increasing number of companies are incorporating initiatives that concern the environment, health and safety into their business operations. These initiatives are not only driven by legislation, but also by customer pressure and new market opportunities. Customers are more environmentally conscious and are pressuring companies to address EHS issues. If the companies do not respond, they risk damaging their reputation and losing market share. On the other hand, environmental issues can also provide new business opportunities for some companies. These companies focus on niche markets and produce "green" products to obtain gain market share.

The implementation of these initiatives and strategies have forced some companies to make major design decisions about their technology and products. For these initiatives to be successful, it is essential that

[5] Figure created by author based on data obtained from R. Balzhiser, "Meeting the Near-Term Challenge for Power Plants," 1989 and J. Roberts, "Note on Contingent Environmental Liabilities," 1994.

decisions are made right the *first* time. This means that all pertinent data must be gathered and evaluated before making a final decision.

2.1. Environment, Health and Safety in the Semiconductor Industry

The semiconductor industry is especially concerned with EHS issues. Fabrication of semiconductor devices requires a variety of process steps -- lithography, etch, oxidation, thin film deposition, diffusion and ion implantation. Each of the steps plays a critical role in transforming the initial silicon wafer into a semiconductor device. Within the process steps there are numerous types of chemicals and materials, some of which are hazardous.

Realizing the environment, health, safety and business risks associated with working with these materials, SEMATECH[6], has created a new focus for the semiconductor industry -- Design for the Environment, Safety, and Health (DESH). SEMATECH incorporated DESH into the Semiconductor Industry (SI) roadmap. The roadmap shows transition of DESH initiatives with each new technology generation through 2010.[7]

In the past, decisions on new semiconductor product designs and processes have focused on yield, costs and logistics.[8] With SEMATECH's focus on EHS issues, along with the heightened awareness of EHS impacts caused by semiconductor fabrication, controlling the use of these materials is becoming a critical issue. Therefore, the semiconductor industry is focusing more on incorporating environment, health and safety concerns into their design and process decisions.

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[6] SEMATECH is a consortium of government and semiconductor companies.

[7] Lashbrook, Wes, "Design for the Environment Safety and Health Programs at SEMATECH," Presentation. September 1996.

[8] Lashbrook, W. and O'Hara, P., "Evaluating the Environment, Safety and Health Impacts of Semiconductor Manufacturing at the Design and Process Development Stages," IEEE/CMPT. Document # 0-7803-3642-9/96, 1996.

3. Overview of Intel

The following chapter provides a brief overview of Intel's organization, and how the environment, health and safety is valued at Intel. The purpose is to provide a better understanding of how the method proposed in this thesis was created and how it can be used within an organization.

3.1. Company Background

Intel ranks as one of the top ten semiconductor companies in the world with estimated semiconductor revenues of over $17 billion for 1996. It is now thought of as potentially becoming one of the world's most profitable companies.[9] Intel's major businesses include microprocessors and specialized semiconductor products. Approximately 50,000 Intel employees in sixteen locations worldwide produce products that are used in cellular phones, automobiles, pagers, personal computers, and networking systems.

Intel was founded in 1968 by two pioneers in the semiconductor industry, Gordon Moore and Robert Noyce. Ever since 1975 when Intel fabricated the world's first microprocessor, the 4004 chip, it has been a dominant player in the semiconductor industry. Intel maintained its leadership with the invention of the i486 microprocessor in 1989, which featured 1.2 million transistors, and most recently with the invention of the Pentium Pro processor.

From its inception, Intel's culture was built on a vision -- to be as innovative about *how* the company works as in *what* products the company makes. Intel's culture focuses on achieving results, taking risks, ensuring quality, and meeting customer requirements. The management at Intel is committed to maintaining a work environment that is safe for the employees and to the surrounding communities. This culture has helped Intel to be as successful as it is today and to be one of the leaders in EHS initiatives.

Intel's success over the past years has led it to aggressively expand globally. This year it announced further expansion plans -- an assembly and test facility in San Jose, Costa Rica and a fabrication facility in Fort Worth, Texas.

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[9] Wall Street Journal article, June 7, 1995, *A Big Bet Made Intel What It Is Today; Now, It Wagers Again.*

3.2. *Intel Corporate*

Figure 3-1 shows a partial organization chart of the Intel Corporation. It primarily focuses on the Technology and Manufacturing Group (TMG). TMG is responsible for environment, health and safety at Intel.

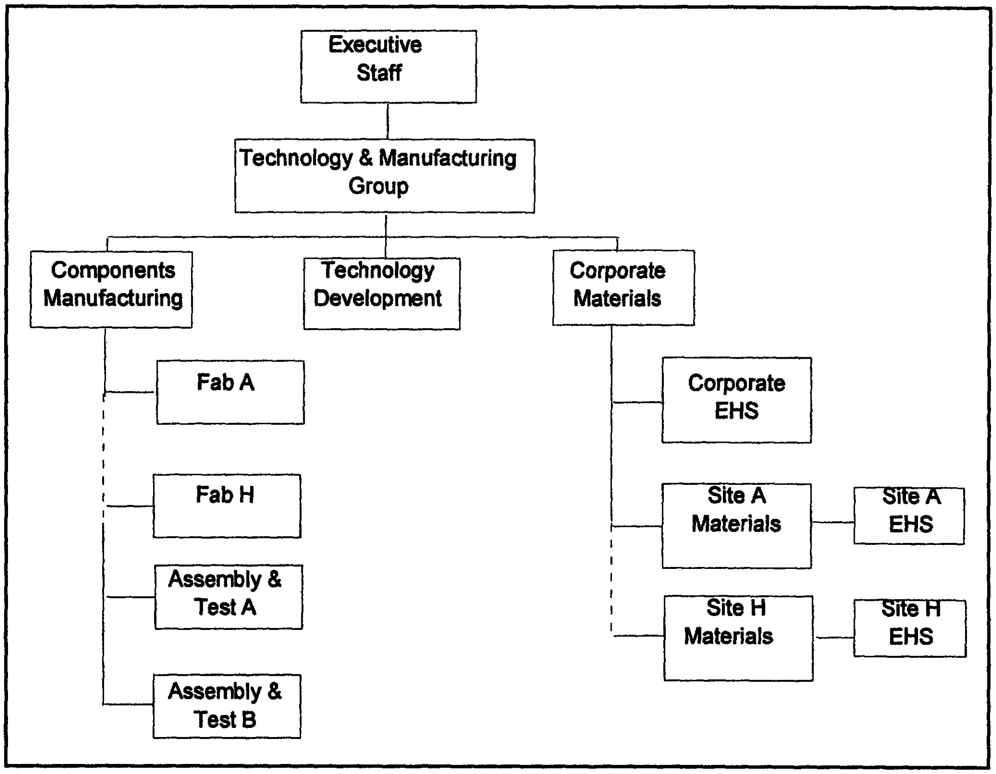

Figure 3-1 Partial Organization Chart of Intel Corporation

3.3. *Design and Manufacturing at Intel*

The Components Manufacturing organization is primarily responsible for fabricating, assembling, and testing semiconductors. It is responsible for fabricating both flash memory and logic technology.

Products and processes are developed by the Technology Development (TD) organization. This organization is responsible for defining the basic sequence of chemical and mechanical steps, the materials, the processes, and the equipment used to fabricate semiconductors. The TD organization also defines the set of design rules for the product-line division to follow when manufacturing next generation of products. Dedicated environmental resources are also available within the TD organization.

3.4. *Environment, Health and Safety at Intel*

Intel's environmental, health and safety organization reports to the Corporate Materials Organization. EHS is separated into two areas -- site specific offices and a centralized corporate office. Site EHS organizations are responsible for waste management, air emissions, water use, waste water and chemical usage specific to individual sites. Each site EHS organization is required to provide relevant EHS training to employees. In addition, each site EHS office is responsible for area regulatory compliance and for community relations pertaining to EHS issues.

Corporate EHS is responsible for generating regulatory reports for the entire corporation based upon the data received from the individual sites, and are responsible for ensuring EHS compliance at new sites. They also act as a liaison between sites for transferring EHS specific knowledge.

As part of Intel's strategy to incorporate environmental initiatives into their business culture, an informal EHS organization was created consisting of three areas -- the Strategic Chemical Council (SCC), a chemical review board, and numerous EHS working groups (WG). The SCC is a senior council that consists of senior management officials from the Technology and Manufacturing organization. The purpose of the SCC group is to address the environmental issues within design, manufacturing and facilities that present some potential level of hazard. The council is responsible for ensuring that environmental improvements are designed into each new generation of technology. Over the past two years, the SCC has provided the leadership within Intel to reduce volatile organic compound emissions, hazardous air pollutants, and global warming gases.[10] The SCC reports dotted-line to the CEO, thereby providing the visibility of EHS issues to high levels of the corporation

The chemical review board reports to the Strategic Chemical Council. This board is responsible for reviewing the chemicals that sites cannot agree to use and for evaluating special chemical requests. The requests that pose a potential hazard to employees or to the environment, or that have been banned for use by the corporation, are sent to the SCC for final review and approval.

Individual working groups have been created as part of a proactive strategy to deal with EHS issues. The group's members are representatives from various Intel sites. These groups are responsible for creating consistency across sites and for developing standard systems and tools that will meet local site

[10] Environmental, Health and Safety at Intel, Intel Corporation, March 1996, p. 8

requirements as well as corporate requirements. These groups focus on a variety of issues such as the development of standardized chemical systems and the reduction of emissions and effluents.

As part of Intel's mission to incorporate EHS into the workplace, fab managers have ultimate responsibility for each of their fab's EHS performance. This type of measurement provides an incentive for managers to focus on EHS issues.

As part of a long-range goal to become the leader in EHS performance within the semiconductor industry, Intel has actively became involved with outside organizations and regulatory agencies. Intel is currently participating in a pilot project with the Environmental Protection Agency's (EPA) called Project XL (eXcellence and Leadership). The goal of this pilot is to create a better system for businesses to improve environmental performance by collaborating with regulatory agencies and with the community.[11]

3.5. Intel's Environment, Health and Safety Concerns

Intel's enormous growth over the past few years has brought on many challenges. To maintain the demand required by its customers, Intel aggressively built new facilities and expanded existing fabs. The growth requires building facilities in a short period of time, while also considering the impact to the surrounding communities and to employee health and safety. Since time is extremely critical in building new sites, Intel is looking at new approaches to meet the administrative requirements of environmental regulations through developing better relationships with local and federal agencies.

Intel's business strategy focuses on accelerated product development, quick technology deployment, platform improvements, manufacturing capacity and worldwide branding. To accomplish this strategy requires continuous improvements and changes. Time and consistency are critical. The issue, therefore, becomes ensuring that decisions, including EHS, are consistent across the business units and that critical data is assessed promptly.

With the increased production and rapid progress in semiconductor manufacturing technology, Intel believes that there are more opportunities to develop new processes and procedures that will reduce the

[11] Environmental, Health and Safety at Intel, Intel Corporation, March 1996, p. 4

burden to the environment. Intel has set internal goals that every new product generation be more environmentally benign than its predecessor.

4. Development of the Evaluation Method

A methodology development team was created to determine Intel's needs for an evaluation process. The team consisted of individuals from the New Mexico Flash Technology organization, a representative from the New Mexico site finance organization, and the author of this thesis. As part of the development effort, the team initially set out to determine Intel's current evaluation process and what areas, if any, were lacking in this process. This was done through surveying multiple Intel sites in the United States -- Arizona, New Mexico, California and Oregon -- and included representatives from process design, facilities, finance, materials, Intel corporate EHS, and site EHS.

The results obtained from the surveys showed that there were four weak areas in Intel's current assessment process. First, Intel's process was inconsistent not only across different sites, but also within the various groups. Second, Intel's process did not emphasize environmental issues and health and safety issues equally. Third, Intel's process evaluated the "hard" costs associated with the acquisition of materials and equipment. It did not include other potential costs associated with EHS issues, such as those for disposal, post-disposal, permits, and facility retrofits. Finally, Intel's evaluation process did not systematically take into account other areas of a project that are difficult to quantify, but have an impact on a business. For example, supplier relationships, manufacturing impact, and equipment installation issues.

The team discovered a variety of environmental methodologies available in the marketplace through researching various publications, efforts being performed at SEMATECH, and the Internet. The research pinpointed three potential evaluation methodologies: Polaroid's Toxic Use and Waste Reduction Program, Bell Laboratories Life-Cycle Analysis, and SEMATECH's CARRI models.

This chapter will explain the three methodologies, their strengths and weaknesses, and how they are applicable to the development of the environmental assessment methodology.

4.1. Polaroid's Toxic Use and Waste Reduction Program (TUWR)[12]

Polaroid's TUWR program focuses on reducing the use of toxic chemicals and the sources of waste. It emphasizes reducing wastes at the source, setting waste reduction targets, and establishing relationships with local communities and environmental groups.

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[12] Stark, Richard D., "Polaroid: Managing Environmental Responsibilities and their Costs," Harvard Business School, 1994, 16.

The strength of the TUWR program is its use of an Environmental Accounting and Reporting System (EARS). EARS is a monitoring system that measures waste generation at the source of pollution. EARS provides a tool for managers to estimate waste implications of proposed new projects. It measures the use of *all* chemicals and the generation of *all* wastes rather than only measuring the *regulated* material. Reports generated by the TUWR program are not distorted by increases and decreases in production since usage and wastes are measured per unit of product.

Although the TUWR system provides an excellent tracking tool for wastes, it is does not provide a method for assessing chemical usage, updates to equipment, or installation of new equipment. In addition, the TUWR program does not account for impacts to employee health and safety.

4.2. Bell Labs Life Cycle Analysis (LCA) [13]

Bell Labs Life Cycle Analysis focuses on evaluating the environmental implications of manufacturing processes throughout their entire life cycle. The overall purpose of the LCA is to minimize the environmental impacts that could occur throughout a product's life cycle. The assessment is based on five life cycle stages of a manufacturing process -- resource provisioning, process implementation, primary process operation, complementary process operations and recycling and disposal. Both quantitative and qualitative data are gathered for each of the stages and a process matrix is created of the environmental stresses that are produced during each stage. An overall environmentally-responsible process rating is computed by summing the values of the matrix elements. The analytical method used in the LCA not only considers the impacts during the manufacturing of a product, but also considers the impacts that occur at the front-end or set-up of a process and at the back-end or disposal process.

Although the LCA is a good tool for assessing the impact that manufacturing processes can have on the environment, it does not consider other criteria that are essential in business investment decisions. The LCA tool is also not capable of performing a financial analysis nor does it address any impacts to employee health and safety.

[13] T.E. Graedel, "Life Cycle Assessment of Electronics Manufacturing Processes," IEEE IEMT Symposium, 1996.

4.3. *SEMATECH's CARRI* [14]

CARRI, which stands for Comprehensive Assessment of Relative Risk Impacts, is a computerized decision-making model created by SEMATECH. The purpose of the model is to provide engineers, managers, and EHS professionals in the semiconductor industry with the tools necessary to evaluate the EHS impacts associated with the selection of chemicals and with the development of new processes.

CARRI consists of numerous databases that contain data of the most commonly used chemicals in the semiconductor industry. These databases characterize chemicals and processes used in fabricating semiconductors according to their hazardous properties. CARRI's strength is its ability to calculate a relative risk impact of process-chemical combinations used in the semiconductor industry through the use of the Analytical Hierarchy Process.[15] This process evaluates how various areas will potentially be impacted. These areas include worker health and safety, general public health, environment, regulations, and cost-of-ownership. An overall relative impact of the process is determined by normalizing the group values, weighting them, and summarizing them. These risk impacts can be used by managers to evaluate alternative chemicals and processes. Since it is a computerized assessment, CARRI performs consistent evaluations of various chemicals and processes, and decreases the amount of effort required to perform time-consuming calculations.

Although CARRI provides an excellent analysis tool for assessing relative EHS risks, it does not address chemical changes or installation of new of equipment. In addition, CARRI's databases are not complete and entering the data required for the databases is extremely labor intensive. Some of the information required by CARRI to characterize the chemical and/or process is process-specific and may not be readily available because of the uniqueness of the process. This is especially true in the semiconductor industry where next generation products will most likely use unique chemicals. Gathering the data required for CARRI is time consuming in these cases. Finally, CARRI's cost-of-ownership module is not complete.

In an industry where it is imperative that decisions are made quickly, CARRI's requirement for this data can cause delays in making these decisions.

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[14] Lashbrook, W. and O'Hara, Patricia, "Evaluating the Environment, Safety and Health Impacts of Semiconductor Manufacturing at the Design and Process Development Stages," IEEE IEMT Symposium, 1996.

[15] Ibid.

4.4. Available Methods Comparison Matrix

The comparison matrix shown in Figure 4-1 was created to summarize the pros of each of the methods mentioned above. The factors, listed vertically in the matrix, were obtained from those mentioned in the individual surveys and from data gathered through research by the development team. The X's show which of the four methods incorporates these factors and the comments section provides additional information not captured in the factor categories. Intel's current evaluation process incorporates many of these factors, but is not consistent across various sites and organizations. This matrix was used as a tool by the team to investigate the strengths from the other methods that could be incorporated into the new evaluation method.

	Methods			
Factors	**Intel's Current Process**	**Polaroid's TUWR**	**Bell Lab's LCA**	**SEMATECH's CARRI**
Considers health and safety issues	X			X
Evaluates impact to air/emissions	X		X	X
Evaluates impact to liquid waste stream	X	X	X	X
Evaluates impact to solid waste stream	X	X	X	X
Evaluates impact to resources			X	X
Considers P^2 hierarchy		X		
Evaluates suppliers /product functionality	X		X	
Considers transportation and logistics impact				
Evaluates total cost of ownership				(In method, but not currently available)
Addresses impact to manufacturing & cycle time				
Considers installation & operational issues				
Comments	• Not a consistent process	• Focuses on manufacturing wastes.	• Focuses on defining the manufacturing environmental impacts.	• Computer decision-making model
		• Links data to long-term environmental improvement	• Addresses recyclability	• Focuses on semiconductor processes.
		• EARS - monitoring system	• Uses a matrix assessment.	• Requires large amount of data

Figure 4-1 Comparison Matrix

5. Evaluation Method Description

To understand the overall EHS affect that a project can have on a business, issues pertaining to both health and safety *and* the environment need to be *equally* considered. The evaluation method that the team developed combines inputs obtained from individuals at Intel, best practices used in other systems, research performed by SEMATECH, and methodologies used in academia. The model considers a variety of factors that are used to determine an overall impact of a proposed project, to the business as well as to the environment, health and safety. This chapter describes the components of the method and how the method is used to evaluate projects. Henceforth, any reference to the evaluation method shall be referred to as "*the method.*"

5.1. Key Areas for Consideration

A variety of areas are considered when evaluating investment projects. When evaluating projects that concern the environment, health and safety, additional areas need to be addressed. These areas include the impact to humans; the impact to the environment; the impact to current and pending regulations; and the impact to the business. The following sections further explain these areas.

5.1.1. Human Impact

When assessing a project, one needs to consider the impact that the project will have on the health and safety of both the employees and the people in the surrounding community. For example, will the project use or produce hazardous materials such as carcinogens, toxins, or flammable substances that could potentially cause harm to employees or to individuals living in the surrounding community.

5.1.2. Environmental Impact

The impacts, negative or positive, that the project will have on the environment should be evaluated and the consequences understood. The environmental impacts refer to air, water or any natural resource. Questions such as the following should be asked:

- Will the project increase or decrease energy use or water consumption?
- Will the project produce hazardous air pollutants?
- Does the project use or produce global warming compounds?
- Will the project impact multi-media? Will the project impact more than one waste stream?

5.1.3. Regulatory Impact

Data should be collected that shows what kind of impact the project will have on federal and local regulations and on future legislation. The information collected should consider how changes to the use of ozone depleting substances, to the amount of hazardous wastes produced, to the concentration of constituents in liquid and solid wastes, and to the waste streams, would affect regulatory requirements.

5.1.4. Business Impact

A financial assessment of the project is required to determine the costs associated with the project and the impact that these will have on a business. In addition, an assessment of how a project will impact the community is also necessary to anticipate future public relation issues. Finally, the project should be evaluated to determine if, and how, it will meet the company's overall strategy and business goals.

5.2. Project Evaluation Process

To ensure that all the key areas are considered when evaluating a project, the team created a process flow that outlines the major steps and provides a high level view of the method. Figure 5-1 shows the high level view of this process. Exhibit 1 shows a detailed view of the method.

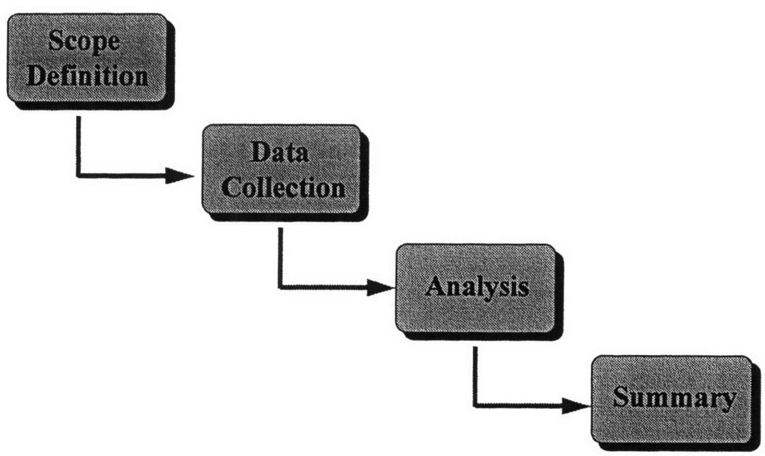

Figure 5-1 Evaluation Process Flow

5.2.1. Scope Definition

The initial step in evaluating a project is to define the scope and the goals of the project. The critical pieces of information that should be included are:

- **Description** - This section describes the project's goals, the time-frame in which the project will start and complete, and any known benefits or risks associated with the project.

- **Multiple site versus single site implementation** - It is important to know whether the proposed project will have an impact on multiple sites or a single site. If there are multiple sites, additional data will need to be collected from all the impacted sites and considered when evaluating the project.
- **Main Driver of Project** - The main driver of the project provides insight during the final decision-making process. Certain drivers hold more weight over others during the final decision. The importance of each driver is dependent upon the goals and strategies of a corporation.

The following is a list of the key drivers used by Intel in order of importance. One driver should be selected for each project:

List of Drivers:

- Support Corporate Goal
- Support a Specific Site Goal
- Support Fab Goal
- Support Business Unit Goal
- Response to a Publicized Pending Regulation
- Improvement to Impacts to the Environment
- Factory Synergy
- Process Improvement
- Permit Limit Condition
- "The Right Thing to Do"

Project drivers are useful in making decisions concerning two or more projects. For instance, the driver of one project could be to support a fab goal to reduce costs. The driver of a second project could be to eliminate a permit limiting condition at a site. If the strategy of the corporation is to ensure compliance, then the decision would select the latter even if the former is more financially appealing.

- **Waste Treatment Options** - The impact that the project will have on waste generation is also important in the decision-making process. There are three processes in which wastes can be handled -- (1) reduce or replace the waste with a less hazardous waste; (2) reuse or recycle the waste to decrease amount disposed; and (3) abate or treat the waste in an environmentally safe manner.

Per the Pollution Prevention Act of 1990, the method of waste treatment prioritizes prevention over "end-of-the pipe" solutions. Therefore, the three methods mentioned above are in order of importance from the highest to the lowest preference of waste treatment options. The team decided to use the Pollution Prevention Act hierarchy when developing the evaluation method. An understanding of how a project affects each of the waste treatment methods provides useful information in assessing the project's importance. One of the three categories listed above should be selected to show how wastes will be treated and affected by the proposed project.

The hierarchy of the waste treatment options is further described below using data obtained from Polaroid's TUWR program.[16] Listed under each category is a prioritized list of waste treatment options for that category.

1. *Reduce or Replace Waste* - Pollution should be reduced at the source or replaced with a non-hazardous or less-hazardous waste whenever possible.
2. *Reuse or Recycle Waste* - Pollution that cannot be prevented should be reused or recycled in an environmentally safe manner.
    - On-site recycle (Closed-loop)[17]
    - Off-site recycle (Closed-loop)
    - Vendor recycle (Open-loop)[18]
3. *Abate or Treat* - Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner.
    - On-site treatment (for recycle, for removal or for "pH control" without recycle)
    - On-site incineration
    - Vendor incineration

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[16] Ahearn, J., Fatkin, H., Schwalm, W., "Polaroid Corporation's Systematic Approach to Waste Minimization," Pollution Prevention Review, Summer 1991.

[17] Close loop refers recycled waste to be used in the original process.

[18] Open loop refers to recycled waste to be used again in a different process.

- Vendor treatment (non-recycle/non-incineration)
- Direct air emission
- Direct sewer discharge
- Vendor land disposal

5.2.2. Data Collection

The second step of evaluating a project is to collect the pertinent data for all the key factors required to assess a project. The data is collected for both a financial and a qualitative assessment. The following describes the data that is required and the criteria used to evaluate the data.

5.2.2.1. Rejection Criteria

Prior to a full-blown data collection analysis, certain criteria should be established to pre-screen a project. A pre-screen is performed to determine those projects that are in conflict with the corporation's goals. If any of the criteria are true, then the project will be rejected and will not require further evaluation. This saves time and effort. The following are examples of fab level rejection criteria that are used at Intel:

- The project will use ozone depleting substances.
- The project will increase fabrication cycle time.
- The project will decrease wafer and/or die yields.

5.2.2.2. Key Categories

The data required focuses on two key categories -- qualitative and financial. Qualitative data consists of the information that is difficult to quantify and financial data consists of the costs associated with implementing the project.

The following is a list of the nine qualitative factors and the specific information required for the qualitative assessment[19]. The list was created based upon inputs from the members on the development team, various representatives from Corporate EHS, process engineers, and facilities engineers at Intel.

Air Impact issues

1. Are any Class I or Class II ozone depleting compounds used?
2. Does the chemical have a low odor tolerance?
3. Are any of the chemicals/compounds global warming compounds?
   If YES, list Global warming compounds that will be used.
4. Will project increase or decrease Perfluorocompound use?
5. Will project increase or decrease hazardous air pollutants?

[19] The information in this exhibit is not intended to be all-inclusive and can be expanded if necessary.

6. Is there any increase in regulated air pollutants that are classified as a major source per USEPA limits?
   If YES, list the air pollutants that are increased.
7. Will project increase or decrease volatile organic compounds?

System/Supplier capability issues

1. Does supplier data support expected functionality of system?
2. Is supplier certified with Intel?
3. Does system use any chemicals, lubricants, gases?
4. Is supplier easy to work with?
5. Has system been tested in industry?
6. What is the supplier's expertise/background with the design/use of their system?
7. Does the system meet the specified requirements?

Resource Consumption issues

1. Will project increase or decrease water consumption?
2. Will project transfer waste streams?
3. How is change in waste stream impacted?
4. Will project increase or decrease energy use?

Liquid waste stream issues

1. Will the project result in a physical change in the exhaust configuration or flow rate?
2. Will the project result in a physical change of the drain system configuration or flow rate?
3. Will the project result in a change of the composition and/or concentration of constituents in the exhaust(s)?
4. Will the project result in a change of the composition and/or concentration of constituents in the liquid waste(s) or waste-by-products?
5. Will the project increase or decrease liquid hazardous waste?

Solid waste stream issues

1. Will the project result in a physical change in the exhaust configuration or flow rate?
2. Will the project result in a physical change of the drain system configuration or flow rate?
3. Will the project result in a change of the composition and/or concentration of constituents in the exhaust(s)?
4. Will the project result in a change of the composition and/or concentration of constituents in the solid waste(s) or waste-by-products?
5. Will the project increase or decrease solid hazardous waste?

Manufacturing impact issues

1. How will project affect yield?
2. Will project impact production for installation?
   If YES, how?
3. Is the probability of that production will be affected HIGH or LOW if the tool or equipment malfunctions?
   Ex. HIGH if tool doesn't have a buffer between it and process tool.
   LOW if tool has a buffer between it and the process tool.
4. Once project is incorporated, how will it impact production throughput and/or equipment availability?

Transportation and logistics issues

1. Will project increase/decrease chemical tracking and/or reporting?
2. Will project require additional controls (hardware/software)?
   If YES, list type(s) of control(s).
3. Are there special container requirements for transportation?

Health and safety issues

1. Will project use Ethylene based glycol ethers that are reproductive hazards?
2. Will project use arsine?
3. Will project use a potential carcinogen?
4. Will project use a known carcinogenic?
5. Will project use a reproductive toxin?
6. Will project use a toxic chemical?
7. Will project use highly flammable substances?
8. Will project potentially harm employees in any other way?

Installation/Operation Issues

1. How much floor space is required?
2. Is space available?
3. Is additional labor required to install or operate equipment?

As is typically done in project assessments, financial data is collected to perform a cost analysis. The costs collected consider the entire life cycle of the project including pre-acquisition, acquisition, use, disposal, and post-disposal. The financial data required is listed below[20]. This list of data was generated by the members of the development team, representatives from Intel's finance organization, and information from SEMATECH's research on design for the environment, health and safety.

Pre-Acquisition

This phase is concerned with the costs associated with research and development, and chemical and equipment selection.

<u>Potential Costs in the pre-acquisition phase:</u>

Labor Costs:

- to determine the chemical or equipment needs
- to assess and qualify suppliers; i.e. review test data; trips to supplier
- to assess logistical impact, e.g. facility changes
- to assess and develop EHS plan for new equipment and chemicals
- to determine process modifications
- to assess EHS risk compared to current process
- to determine requirements for regulatory compliance - e.g. permits, manifests, training, inspections, reports, chemical mass balance
- to determine waste emission impact on community

[20] Although this is a detailed list, it is not meant to be all-inclusive.

- to develop the strategy and tactical plans to manage and control the EHS issues determined above. e.g. pollution prevention; chemical safety and health management; engineering controls; factory-process modifications; prepare hazardous waste procedures; prepare waste/emission reduction plans

Expenses:
- for chemical sampling

Capital Costs:
- necessary to develop supplier capability

Acquisition
This phase is concerned with the costs associated with acquisition, installation and pre-testing of selected chemicals and equipment.

Potential Costs in the acquisition phase:
Labor Costs:
- to determine building requirements/changes that are necessary to be compliant and obtain approvals
- to determine EHS requirements that are necessary to be compliant and obtain approvals
- to assess internal business objective compliance
- to develop, negotiate and sign-off supplier contracts
- to assure product quality
- to determine requirements for start-up
- required to coordinate the logistics of transportation - supplier to factory; factory to manufacturing process
- to set up receiving and delivery systems

Expenses:
- Building Permit fees
- EHS Permit fees
- installation costs
- other permit type fees
- additional installation costs
- additional engineering services
- insurance for carriers
- raw materials (chemicals)
- packaging supply costs - totes; drums; containers
- additional trips to suppliers
- associated with operational testing
- associated with purchase of additional HAZMAT response vehicles
- of storage facilities and hardware requirements

Capital Costs:
- to create necessary infrastructure
- for additional infrastructure capital
- to purchase hardware (equipment)

Use
This phase includes the costs associated with the productive use of chemicals and equipment.

Potential Costs in the use phase:

Labor Costs:

- to distribute gas, bulk chemicals, & manually pour chemicals
- required to track inventory (track spoilage, inventory, capture/reuse)
- required to mix/blend chemicals for production
- required to track and control chemical usage
- required for data collection, reporting, emissions monitoring, and complying with environmental regulations
- to monitor chemical safety, comply with the safety and health regulations, and monitor industrial hygiene
- required to perform preventive maintenance on Life Safety Systems

Disposal

This phase includes costs incurred when a chemical no longer adds any value to manufacturing a product and exists on the factory site.

Potential Costs in the disposal phase:

Labor Costs:

- to collect, consolidate, & dispose waste
- to characterize waste
- to manage recyclable drums
- to recycle material (clean bottles, breakdown boxes, rinse/crush)
- to perform preventative maintenance on waste collection systems
- to prepare and package containers for transport
- to prepare required documentation
- to maintain disposal records-hazardous waste, mass balance, TRI's (SARA 313)
- to perform audits and inspections
- to report hazardous material transportation fees to DOT
- to track suppliers
- required to define, negotiate and define disposal supplier contracts
- required to manage disposal supplier, i.e. invoices, contract changes, growth

Expenses:

- disposal fees
- waste packaging cost
- waste treatment prior to disposal cost
- waste shipping/transport cost
- waste characterization costs
- hazardous materials fees
- for containment storage area
- for waste collection hardware (piping, tanks, pumps, etc.)
- for wastewater treatment (HF treatment sludge, etc.)
- for waste container costs (bottles, boxes, 55 gal drums, tri-wall containers, totes, etc.)
- for bottle wash and treat
- to use water required for cleaning process
- for treatment for water waste
- of recycled drum supplier
- for transportation to recycle drums.
- of storage area prior to shipment
- of waste sampling costs

- of carrier insurance/liability (off-site response)
- of trips to suppliers for business review meetings

Post-Disposal
This phase includes the costs associated with managing a chemical when it has left control of the factory where it was generated.

Potential Costs in the post-disposal phase:
Labor Costs:

- required to monitor disposal site for regulatory compliance (inspections, manifesting, etc.)

5.2.3. Analysis

The analysis portion of the process flow performs two distinctive evaluations -- one on the qualitative data and the other on the financial data. The team based the analysis of the qualitative data on the concept scoring approach described by Eppinger and Ulrich, 1995.[21] This approach was selected to better differentiate between competing projects.

The financial analysis is based on a life cycle and activity based costing approach developed through joint research of Oregon State University, Wright, Williams & Kelly, and SEMATECH.[22] A net present valuation is used to determine the financial impact of the project.

5.2.3.1. Qualitative Analysis

The concept scoring approach determines a weighted score for each project. The scores are calculated by multiplying the ranks determined for each of the factors by the decision weights assigned to the factor. The total score for each project is the sum of the weighted scores. Equation (1) shows this calculation.

$$\text{Project Score}_k = \sum_{j=1}^{m} \left(FR_{jk} * DW_j \right) \qquad (1)$$

where FR_{jk} = factor rating for project k for the jth factor

DW_j = decision weight for factor j

m = number of factors (in this case, $m = 9$)

Project Score_k = total score for project k

The project score is then compared with other possible projects. The project with the highest score is the one that best meets the business goals and will have the most positive impact if implemented.

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[21] Eppinger, S., Ulrich, Karl, Product Design and Development, McGraw-Hill, 1995.

[22] Dance, D., Dr. Veltri, A., and Lashbrook, W., "Applications of Cost of Ownership to Environment, Safety and Health," IEEE/CMPT, # 0-7803-3642-9/96, 1996.

Assigning Factor Weights

The nine factors -- employee health and safety, air emissions, solid waste, liquid wastes, supplier capabilities, resource consumption, manufacturing impact, installation/operation concerns, and transportation/logistics issues are first given a "weight" determined by the decision-making team. This weight is based on the importance that each factor has on the business and on the goals of the decision-team. The "weight" value is any integer from zero through ten. Ten is assigned if the impact produced by the project, whether negative or positive, is *critical* to the final decision or to the business. A zero is assigned to a factor if the impact produced by the project is of *no importance* to the decision or to the business.

Determining the Factor Rank

Each factor is then ranked based upon its performance in a specific project. The purpose of ranking each factor is to determine what kind of impact can be expected if a project is implemented. A positive rank signifies that the project will improve the current situation and a negative rank signifies that the project will worsen the current situation.

A value between -5 and +5 is assigned to each question in Section 5.2.2. These values are assigned based on the specific response received for each question and on the level of impact on the environment, on employee health and safety, on manufacturing, and on start-up issues. Exhibit 2 shows a matrix of the these values cross-referenced to the question responses.

The overall factor value is determined by averaging the values from Exhibit 2 and all the *applicable* questions associated with each factor. For example, the Air Quality factor has eight questions and twenty-four possible answers. Only one response is allowed for each question. An average of the responses is calculated and assigned to the air quality factor. If a response is not applicable ("N/A"), then it is not considered when calculating the average for that specific factor category.

A negative overall factor average signifies that the specific project in question will have a detrimental effect on that certain factor. An average of "-5" indicates that the project will have a *significant* adverse impact. A positive average, on the other hand, signifies that there will be an improvement to the specific factor. A "+5" indicates a *significant* positive impact or improvement.

Figure 5-2 shows an example of the matrix used in the qualitative analysis. The total scores calculated for the two projects show that Project 2 has a higher value. As you can see from the figure, supplier and product capabilities, transportation and logistics, and installation and operation factors play a key role in calculating the final project scores. The supplier and product capabilities were important in the final decision as noted by the high value assigned to the decision weight. Since Project 2 had a higher supplier capability factor rank, 5, versus zero for Project 1, the weighted value for supplier capabilities was 45 for Project 2 and zero for Project 1. Similar differences can be seen in the transportation/logistics and installation/operation factors. These three factors had the greatest impact on the final score calculations. Project 2 has the highest score and therefore meets more of the organization's goals.

Decision Criteria	Decision Weight (0 to 10)	Proposed Projects			
		Project 1		Project 2	
		Rating	Weighted Score	Rating	Weighted Score
Health and Safety	8	5	**40**	5	**40**
Air Impact	3	5	**15**	5	**15**
Resource Consumption	5	-5	**-25**	-5	**-25**
Liquid Waste Stream	0	0	**0**	-2.5	**0**
Solids Waste Stream Impact	0	0	**0**	-1	**0**
Manufacturing Impact	10	4.5	**45**	4.5	**45**
Supplier / Product Capability Issues	9	0	**0**	5	**45**
Transportation / Logistics Issues	4	-2	**-8**	0	**0**
Installation / Operations Issues	6	-2	**-12**	0	**0**
	Total Score		**55**		**120**

Figure 5-2 Assessment Matrix

5.2.3.2. Financial Analysis

Typically, business investment analyses do not account for EHS costs associated with a product or process. The evaluation method developed by the team does incorporate these costs. The method uses a life cycle and activity based costing approach to perform the financial assessment for a project. This approach ensures that all the costs incurred throughout a project's entire life cycle are considered in the assessment. The life cycle consists of five phases: pre-acquisition (research and development), acquisition, use, disposal and post-disposal.

A net present value calculation is performed on the significant costs and savings associated with each project. Since the purpose of the financial assessment is to provide a high level view of the project costs, only those that are significantly different are considered. Project costs are considered significant if they differ greatly compared to a baseline. For instance, if two or more projects are being assessed, then one of the projects is chosen to be the baseline for the comparison. Any costs that are extremely higher or lower than the baseline project are considered in the net present cost evaluation. If there is only one project being evaluated, then the current situation at the company is used as the baseline for the comparison. The purpose of this approach is to minimize the level of effort required to capture the costs of the project. The costs that are similar in magnitude are irrelevant in the financial comparison.

The Net Present Value (NPV) technique evaluates the value today (present value) of some future income or expense. For reference in this thesis, this expense refers to the investment project. NPV is computed using the cash flows over a project's economic life, and then converts these to a present value. To calculate the present value, expected future payoffs (or costs) of the project are discounted by the rate of return or hurdle rate. This rate is determined by the return that is foregone by investing in a project rather than in comparable investment alternatives.

As was mentioned above, the financial assessment is not intended to perform a full blown financial analysis on all the projects being considered, but rather to determine the major cost differences. This reduces the effort required to perform the cost analysis. A detailed cost analysis can be performed once a final project is selected. This analysis is not part of the method described here.

5.2.4. Summary/Results

The results provided by the financial and the qualitative assessments provide a complete picture to management to make well-informed decisions about investment projects. A summary report is generated for management to review the results and compare the project options.

The following is a summary report recommended by the team. It is divided into six sections:

Section I - High Level Summary - A summary of the project scope, drivers, and affects pollution prevention initiatives.

Section II - Outstanding Information and Action Items - A list of action items and outstanding information is generated from the responses obtained during the data collection phase. This list makes the decision-makers aware of what information is lacking before making a decision. The decision-makers can either (1) choose to make a decision without the information or (2) require that the data be obtained before making a decision.[23]

Section III - Benefits and Concerns - Based upon the responses, a list of the benefits and concerns for each project is generated.

Section IV - Financial Assessment Results - The results from the net present value calculation are listed.

Section V - Matrix Analysis - The results of the matrix analysis are provided.

Section VI - Rejection of Project - If a project was rejected, this section lists the reason for the rejection.

An example of this summary report can be seen in Exhibit 3. As is shown, the first section summarizes the purpose and goal of the project. The next section lists check boxes of the actions that are required to be performed. The next section lists the benefits and concerns associated with the project. The final section lists the results of the financial assessment.

5.2.4.1.Bulls Eye of Results

Once the data is collected and an analysis is performed for all projects in question, a quick comparison of the projects can be shown in a bulls eye chart. Figure 5-3 shows an example of a bulls eye chart. The rings represent values from -50 to +50. The intersecting lines represent each of the nine qualitative factors. The best score that can be achieved from the matrix assessment is 50 (decision weight = 10 and factor rank = +5). The worst score is -50 (decision weight = 10 and factor rank = -5). Therefore, the center bulls eye ring has a value of 50 and the farthest outside ring has a value of -50. The corresponding factor rank determined during the matrix assessment is plotted on the graph. The projects with factor ranks closer to the bulls eye more closely meet the corporation's goals. The factor ranks located on the outside rings show the areas of concern. These factors should be evaluated more closely before implementation.

5.2.4.2.Software Tool

Using Visual Basic, the author created a software tool to support the evaluation method. The tool minimizes the level of effort required to perform an evaluation. The software program queries the user to input the data required by the method. Then, through various macros, the software program performs the qualitative and financial assessments. The result is a summary report similar to the one mentioned in

[23] A word of caution - the missing information will not be included in the calculations performed for the matrix analysis.

Section 5.2.4. The summary report shown in Exhibit 3 is automatically generated based on the responses to the questions. The boxes are checked if further action is required.

Samples of the screens created in the Visual Basic program can be found in Appendix A.

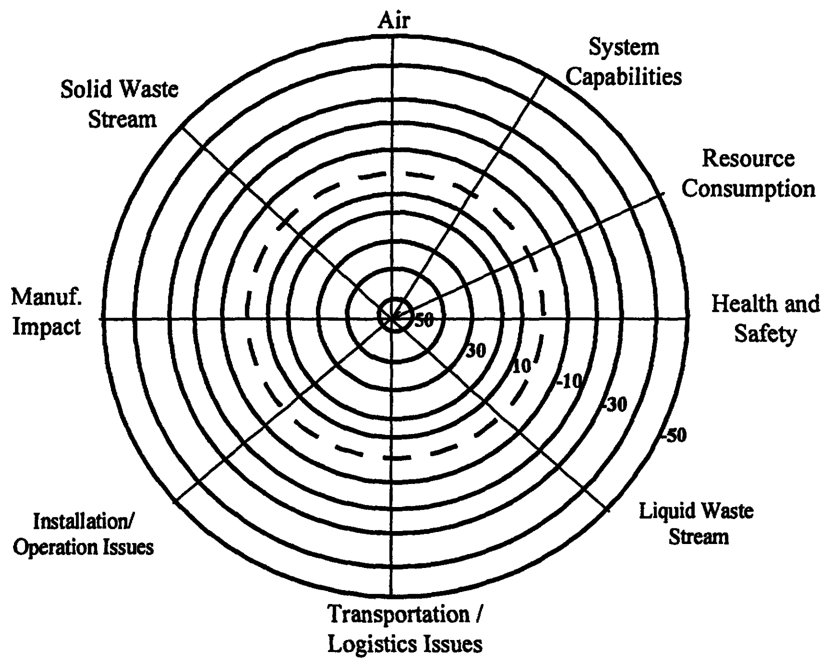

Figure 5-3 Bulls Eye Chart Example

6. Evaluation Method Example

The above method was tested at Intel on a Perfluorocompound (PFC) capture and recycle system. The PFC system includes equipment and labor required to capture PFCs, pre-treat PFCs to remove caustics, and recycle PFCs. The recycled PFCs would then be used in alternative processes external to Intel. The evaluation method was used to decide among three PFC system suppliers. The PFC evaluation team at Intel consisted of representatives from the Santa Clara and Portland Technology Development organizations, Corporate EHS, Chemical Systems, Corporate Capital Acquisitions, Facilities Technology, Flash Technology Development, and Finance.

6.1. Project Definition

The purpose of the project was to implement a PFC recovery system that would be installed across multiple Intel sites. The system was required to capture greater than 80% of the PFCs currently used in the fabrication of semiconductors.[24] The project was driven by a potential regulation concerning Global Warming Compounds. The U.S. government signed an international accord committing the U.S. to reduce all Global Warming Emissions to 1990 levels by the year 2000. In response to this, Intel decided to reduce the total amount of PFCs that the corporation was emitting into the atmosphere. In meeting pollution prevention (P^2) goals, the project focused on the second level in the P^2 hierarchy -- reuse and recycle.

6.2. Qualitative Analysis

The PFC evaluation team first assigned each of the nine factors a decision weight based on Intel's goals and the team's goals.

6.2.1. PFC Project Decision Weights

Figure 6-1 summarizes the decision weights that the team assigned to each of the nine factors. It also provides a brief explanation for their choice of weights. For example, since the PFC team considered that any impact the project would have on wafer fabrication would be critical, they gave the factor, Manufacturing Impact, a '10.' Since the PFC team considered the impact that the project would have on solid and liquid waste streams to be minimal or none at all, they gave the factors, Solid and Liquid Waste Stream Impact, a zero.

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[24] The specific PFCs to be captured by the system were CF_4, C_2F_6, NF_3, SF_6, and CHF_3.

Factor	Decision Weight	Rationale
Manufacturing Impact	10	It was critical to the team that the project not impact the production of wafers.
Supplier/Product Capabilities	9	It was important to the team that the supplier system be capable of recovering >80% of PFCs.
Health and Safety Impact	8	The team ranked H&S high since it is highly valued at Intel.
Installation/Operation Issues	8	Since fab and sub-fab floor space is limited, the team decided installation requirements to be critical to the final decision. Additional labor to operate equipment was also important.
Resource Consumption	5	The team was moderately concerned with the amount of resources (water, energy) that would be consumed.
Transportation/Logistics Issues	4	The team was moderately concerned about tracking, control systems or container requirements associated with the proposed systems.
Air Impact	3	The team felt that since the goal of the project was to reduce the impact to air, this factor was valued lower because all the projects have the same air goals.
Solid Waste Stream Impact	0	Since this project would not impact solid or waste streams, it was not an important issue to the team.
Liquid Waste Stream Impact	0	

Figure 6-1 PFC Factor Weights

6.2.2. Factor Rank Calculation

Next, pertinent data was collected for each option. Considering this data, a rank was determined for each of the nine factors for the three options. The factor ranks are highlighted and are labeled *Category Average* in Figures 6-2 and 6-3. The averages are calculated based upon the answers to the questions listed under each factor. These questions are generated from the list in Section 5.2.2.2 - Key Categories.. If the question is not-applicable (N/A) for the assessment, it is assigned an 'X' and is not considered when calculating the average. For example, under the Manufacturing Impact factor, the first question is whether the proposed project will have an impact on yield. Since the PFC project consists of equipment to be installed on the back-end of the production process, it will not impact the fabrication process or yield. Therefore, the impact to yield is not-applicable for the assessment and is given an 'X.' On the other hand, the installation of the PFC equipment could potentially have an impact on production. Therefore, the two questions -- will the project impact production during installation and is there a high or low probability that the project would have an impact on production if the PFC tool malfunctions -- are applicable. As can be seen from Figure 6-3, there is *no* impact to production during installation and the probability of manufacturing impact due to equipment failure is *low*. Based on these responses, the chart in Exhibit 2 is cross-referenced and the response to each question is assigned a value. The value listed under the *no* response is 5 and the value under the *low* response is a -1. The average calculated for the Manufacturing Impact factor it therefore, 2.

6.2.3. Matrix Assessment

Combining the decision weights and the factor ranks, a final score was calculated for each of the options. As shown in Figure 6-4, the final score for Option A was 38, for Option B was 41, and for Option C was -47. These scores were calculated based on the decision weights assigned by the PFC team, the ranks calculated for each factor, and equation (1). Since Option C produced a score that was not close to either Option A or Option B, and was highly negative, it was decided not to pursue this option. The rest of the evaluation focused on Option A and Option B.

6.2.4. PFC Bulls Eye Summary

From the results calculated in the qualitative assessment, a Bulls Eye Summary chart was created for the PFC project. The chart provided a graphical image of the results to view the pros and cons associated with the three options. As shown in Figure 6-5, there was a concern with health and safety if Option C was selected. There was also a concern with resource consumption across all options. The closer the value was to the bulls eye, the more likely the option met the goals of the evaluation team. The farther away the value was from the bulls eye, the higher the likelihood that the project would cause problems concerning that specific factor.

		Option A	Rnk	Option B	Rnk	Option C	Rnk
Air Impact	• Uses ODCs	N/A	X	N/A	X	N/A	X
	• Low Odor Tolerance	N/A	X	N/A	X	N/A	X
	• GW Compounds	NO	5	NO	5	NO	5
	> 1995 emission levels	N/A	X	N/A	X	N/A	X
	• Use/Create PFCs	DECREASE	5	DECREASE	5	DECREASE	5
	• Use of HAPS	N/A	X	N/A	X	N/A	X
	• Use of VOCs	N/A	X	N/A	X	N/A	X
	• Air Permit Impact - Usage	N/A	X	N/A	X	N/A	X
	2 *Number of applicable questions*						
	CATEGORY AVERAGE =		5.0		5.0		5.0
System/Supplier Capabilities	• Supplier Data Available	YES	5	YES	5	YES	5
	• Supplier Certification	YES	5	YES	5	YES	5
	• Chemical Use	NO	5	NO	5	NO	5
	- New ?	N/A	X	-	X	-	X
	• Is the supplier easy to work with?	NO	-5	YES	5	YES	5
	• Is system tested in industry?	YES	5	NO	-5	NO	-5
	• Supplier expertise	HIGH	5	MEDIUM	3	MEDIUM	3
	• System meets requirements	MEDIUM	3	MEDIUM	3	HIGH	5
	7 *Number of applicable questions*						
	CATEGORY AVERAGE =		3.3		3.0		3.3
Resource Consumption	• Water Consumption	N/A	X	N/A	X	N/A	X
	• Transfer Waste Streams?	N/A	X	N/A	X	N/A	X
	• Energy Use	INCREASE	-5	INCREASE	-5	INCREASE	-5
	1 *Number of applicable questions =*						
	CATEGORY AVERAGE =		-5.0		-5.0		-5.0
Liquid Waste Stream	• Physical change in exhaust configuration or flow rate.	N/A	X	N/A	X	N/A	X
	• Physical change in drain system or flow rate.	N/A	X	N/A	X	N/A	X
	• Change in composition or concentration of continuents in exhausts.	N/A	X	N/A	X	N/A	X
	• Change in composition or concentration of constituents in liquid wastes or waste by prod.	N/A	X	N/A	X	N/A	X
	• Hazardous Waste	N/A	X	N/A	X	N/A	X
	0 *Number of applicable questions*						
	CATEGORY AVERAGE =		0		0		0
Solid Waste Stream	• Physical change in exhaust configuration or flow rate	N/A		N/A		N/A	
	• Physical change in drain system or flow rate.	N/A		N/A		N/A	
	• Change in composition or concentration of continuents in exhausts.	N/A		N/A		N/A	
	• Change in composition or concentration of constituents in liquid wastes or waste by prod.	N/A		N/A		N/A	
	• Hazardous Waste	N/A		N/A		N/A	
	0 *Number of applicable questions*						
	CATEGORY AVERAGE =		0		0		0
Manufacturing Impact	• Yield Impact	N/A	X	N/A	X	N/A	X
	• Impacts production for installation.	NO	5	NO	5	NO	5
	- If YES, Requires Equip shut-down	N/A	X	N/A	X	N/A	X
	- If YES, Length of impact	N/A	X	N/A	X	N/A	X
	Probability of impact to prod'n due to tool malfunct.	LOW	-1	LOW	-1	LOW	-1
	Impact to prod'n throughput or equip. availability	N/A	X	N/A	X	N/A	X
	2 *Number of applicable questions*						
	CATEGORY AVERAGE =		2.0		2.0		2.0

Figure 6-2 PFC Project Factor Ranking

		Option A	Rnk	Option B	Rnk	Option C	Rnk
Transportation/ Logistics Issues	• Tracking/Reporting Effort	INCREASE	-5	INCREASE	-5	INCREASE	-5
	• Additional Controls	NO	5	NO	5	NO	5
	• Special Container Requirements	YES	-5	YES	-5	YES	-5
	3 *Number of applicable questions*						
	CATEGORY AVERAGE =		-1.7		-1.7		-1.7
Health and Safety Issues	• Uses Ethylene based glycol ethers that are reproductive hazards	N/A	X	N/A	X	N/A	X
	• Uses arsine	N/A	X	N/A	X	N/A	X
	• Uses Carcinogen	N/A	X	N/A	X	N/A	X
	• Uses potential carcinogen --- eg. - Tricholoroethylene - Carbon Tetrachloride (ODS) - Chloroform	N/A	X	N/A	X	N/A	X
	• Uses a reproductive toxin	N/A	X	N/A	X	N/A	X
	• Uses a Toxic Chemicals	N/A	X	N/A	X	N/A	X
	LD50 (mg/kg) 4 hr. LC50 (ppm)						
	extreme 1 <10	-		-		-	
	highly 1-50 10-100	-		-		-	
	moderate 50-500 100-1,000	-		-		-	
	slight 500-5,000 1,000-10,00	-		-		-	
	non-toxic 5,000-15000 10,000-100,0	-		-		-	
	Approaches threshold dose for toxicity	-		-		-	
	• Other impact to harm employees	NO	5	NO	5	YES	-5
	• Uses highly flammable substances	N/A	X	N/A	X	N/A	X
	1 *Number of applicable questions*						
	CATEGORY AVERAGE =		5.0		5.0		-5.0
Installation Operation Issues	• How much floor space is required	MEDIUM	-3	MEDIUM	-3	LARGE	-5
	• Additional labor req'd for install/oper'n	YES	-5	YES	-5	YES	-5
	2 *Number of applicable questions*						
	CATEGORY AVERAGE =		-4.0		-4.0		-5.0

Figure 6-3 PFC Project Factor Ranking (continued)

Factor	*Decision Weights (0 to 10)*	*Proposed Projects* Option A FR	FS	Option B FR	FS	Option C FR	FS
Air Impact	3	5	15	5	15	5	15
System/Supplier Capability	9	3	27	3.3	30	3.3	30
Resource Consumption	5	-5	-25	-5	-25	-5	-25
Impact to Waste Stream - Liquids	0	0	0	0	0	0	0
Impact to Waste Stream - Solids	0	0	0	0	0	0	0
Manufacturing Impact	10	2	20	2	20	2	20
Issues concerning Transportation / Logistics	4	-1.7	-7	-1.7	-7	-1.7	-7
Impact to Health & Safety of Employees	8	5	40	5	40	-5	-40
Installation/Operation Issues	8	-4	-32	-4	-32	-5	-40
	Option Total Score		38		41		-47

FR = Factor Rank
FS = Factor Score

Figure 6-4 Matrix Results for PFC Evaluation

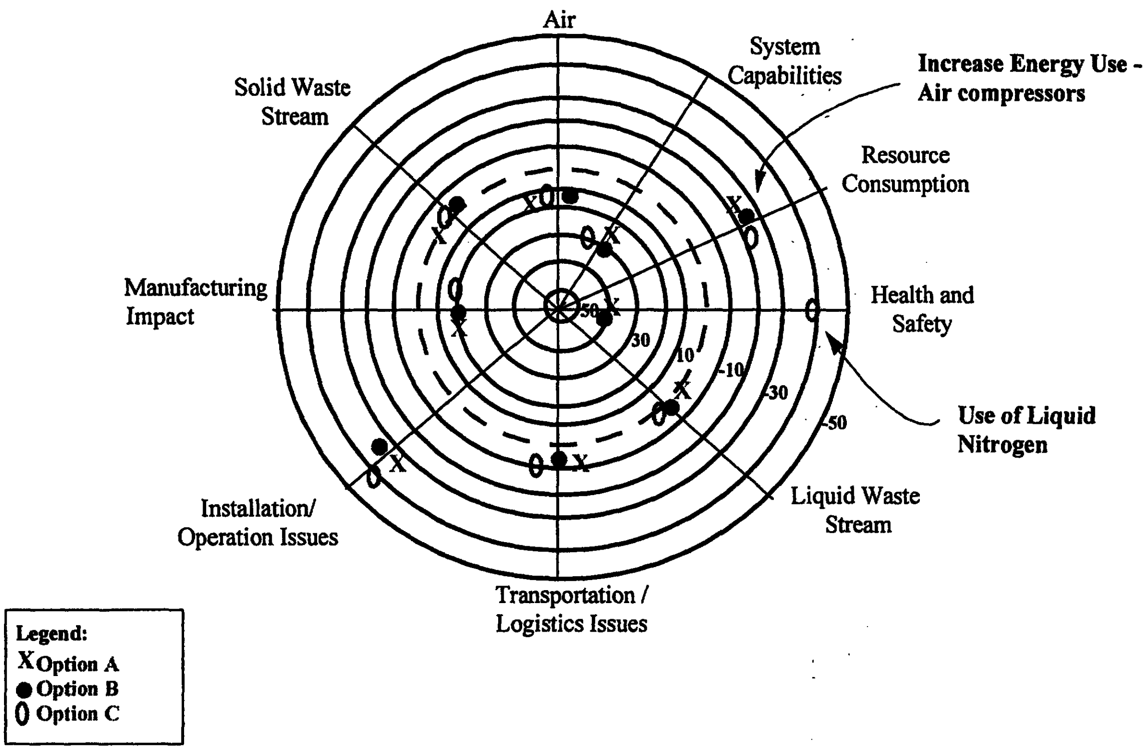

Figure 6-5 PFC Bulls Eye Chart

6.3. Financial Analysis

With Option C eliminated, a high level cost assessment was performed on Options A and B. Life cycle costs were gathered for each option. A comparison was then performed to determine the activities that had the highest cost variances and that were unique to each project.

The life-cycle cost comparison of the activities associated with the PFC project can be seen in Figure 6-6. The comparison of the costs indicated that there were five areas (shown in the figure by arrows) with major cost variances -- system hardware lease, system hardware purchase, raw material (spare parts), system support, and storage space requirements. The other activities listed in the figure had costs that were either the same or very similar between the two options and were, therefore, not significant for the high-level financial assessment.

A net present value was then calculated using these costs. The project lifetime was five years, and the hurdle rate used by Intel for the proposed project was 8%.[25] The NPV of Option A for a five year lease

[25] The hurdle rate and the cost numbers presented in the NPV calculations have been altered to protect the proprietary data of Intel and of the PFC suppliers.

was ($558,660). The NPV of Option B was ($1,665,120). The detailed NPV analysis can be seen Figures 6-7 and 6-8.

PFC - Costs Comparison
Option A vs. Option B Costs

	Costs A	(notes)	Costs B	(notes)	Major Cost Variances?
Pre- Acquisition					
Labor to assess equip. and suppliers	X		X		*Same*
Equipment testing					*Same*
Acquisition/Start-Up					
Project Management	X		X		*Same*
Building permit fees	X		X		*Same*
Installation Costs					*Same*
Interconnect piping & utilities	X		X		
Fit-up and Hook-up of equip	X		X		
Exhausts and ventilation systems	X		X		
Telephone line for tele-monitoring device	X		X		*Same*
Floor Space	X		X		*Same*
Labor to connect FAST & FMS to system	X				*Same*
System Hardware (lease option)	X	$11,660/mo	X	$28,920 / mo	
System Hardware (purchase option)	X	$297,880 (purchase)			
Office space for supplier rep	X		X		*Same*
Raw Materials					
Feed Gas			X		*Same*
Spare Parts (*if Option A purchased*)	X	$4,644 (total)			
Consumables after 1 year (100 scfm)		$2,000 (*note 1*)			
Non consumables after 1 year (100scfm)		$2,644 (*note 2*)			
System Support (*if Option A purchased*)					
Senior Technician	X	$2,800/mo			
Emergency Services	X	$30/hour			
On-Site Testing	X		X	alpha prototype being evaluated at Intel	*Same*
Training Intel Employees	X		X		
Operation of systems					*Same*
Emergency training					*Same*
EHS effort for installation	X		X		*Same*
Use/Operations					
On-Going/On-site Support					
Opn's personnel to staff opn's	X		X		*Same*
Emergency response support	X		X		*Same*
Storage Space for on-site of cylinders & spare parts	X	N/A if lease	X	$70, 000 (*notes 3, 4*)	
Utility Usage					*Same*
Electricity	X		X		
Water	X		X		
Monitor scrubber gas supplied from scrubber to PFC sys.	X		X		*Same*
Disposal					
Transportation of PFC to off-site recycler	X		X		*Same*
Cylinders to store PFCs	X		X		*Same*
Post Disposal					
N/A	N/A		N/A		*N/A*

Notes

1 **Purchase of consumables - annually *(applicable only if Option A system purchased)***
2 **Purchase of non-consumables *(applicable only if Option A system purchased)***
3 **Cylinder storage area assumed to be 70 sq. ft.**
4 **Fab Square footage cost = $100/sq. ft**

Figure 6-6 PFC Example - Life Cycle Costs Comparison

Option A Net Present Cost	Year 0 1997	Year 1 1998	Year 2 1999	Year 3 2000	Year 4 2001	Year 5 2002	Year 6 2003	Year 7 2004	Year 8 2005	Year 9 2006	Year 10 2007
						Cash Flows					
Pre- Acquisition											
Acquisition/Start-Up											
System Hardware (5 yr lease)		(139,920)	(139,920)	(139,920)	(139,920)	(139,920)					
System Hardware (10 yr lease)		(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)
System Hardware (purchase)		(297,880)									
Raw Materials											
Spare Parts *(req'd if purchased)*	0	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)	(4,644)
Use/Operations											
Storage Space for on-site cylinders		(70,000)	(70,000)	(70,000)	(70,000)	(70,000)	(70,000)	(70,000)	(70,000)	(70,000)	(70,000)
System support (supplier rep)		(2,800)	(2,800)	(2,800)	(2,800)	(2,800)	(2,800)	(2,800)	(2,800)	(2,800)	(2,800)
Disposal											
Post Disposal											
TOTAL - 5 YR LEASE	0	(139,920)	(139,920)	(139,920)	(139,920)	(139,920)					
TOTAL - 10 YEAR LEASE	0	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)	(108,000)
TOTAL - PURCHASE (10 yr life)	0	(375,324)	(77,444)	(77,444)	(77,444)	(77,444)	(77,444)	(77,444)	(77,444)	(77,444)	(77,444)

NPV - 5 year lease	($558,660)
NPV -10 year lease	($724,689)
NPV -Purchase(10 yr)	($795,470)

Figure 6-7 Net Present Value Calculation - Option A

Option B Net Present Cost	Cash Flows					
	Year 0 1997	Year 1 1998	Year 2 1999	Year 3 2000	Year 4 2001	Year 5 2002
Pre- Acquisition						
Acquisition/Start-Up						
System Hardware (5 yr lease option)		(347,040)	(347,040)	(347,040)	(347,040)	(347,040)
Raw Materials						
Spare Parts		N/A	N/A	N/A	N/A	N/A
Use/Operations						
Storage Space for on-site cylinders		(70,000)	(70,000)	(70,000)	(70,000)	(70,000)
System support (supplier rep)		N/A	N/A	N/A	N/A	N/A
Disposal						
Post Disposal						
TOTAL - 5 YR. LEASE	0	(417,040)	(417,040)	(417,040)	(417,040)	(417,040)

NPC - 5 year lease **($1,665,120)**

Figure 6-8 Net Present Value Calculation - Option B

6.4. Results

The matrix assessment showed that the final score for Option A was slightly higher than that for Option B. After performing the financial assessment, Option A again proved to be more worthwhile. The present value of Option A's costs was approximately one-third of Option B. Option A was superior in both the qualitative assessment and the financial assessment and was therefore selected from the three options.

6.5. Reflection

It is important to consider the results from both the qualitative and financial assessments when making a decision. Although in this example, both assessments pointed the decision in the direction of Option A, it could have turned out differently. For instance, if the result of the qualitative assessment showed that score of Option B was much higher than Option A, but that Option B's costs were three times as much as Option A's, then the decision would have been much more difficult. At this point, the decision-makers would have to decide whether the larger investment was more valuable in the long term because it provided better qualitative benefits (See Figure 6-5 for the results that are closer to the bulls eye). This would have to be compared to the other option, which has a smaller investment, but was more risky.

6.6. Comparison of Current System versus the Evaluation Method

The use of this method proved to be worthwhile to Intel in that it provided additional information that the PFC team did not consider. The method provided a more detailed cost evaluation that included EHS costs, disposal costs, and post-disposal costs. These costs were not included in the current Intel financial analysis process. The results also provided the PFC team with a consistent method and a summary report that listed all critical information required to make a decision.

The use of the method recommended the selection of the same option as the PFC team had selected using the current evaluation process. The method, however, provided analytical data that not only supported the selection of Option A, but to also supported the decision to eliminate Option C early in the process. In addition, the NPV evaluation included other use-phase costs that were not accounted for in Intel's NPV analysis. The method provided a more realistic view of all the costs that would be incurred when implementing the project.

Finally, the method offered an additional analysis tool, the bulls eye chart. This chart provided the PFC team with a tool that summarized the benefits and concerns with the projects based upon the team's priorities and goals.

6.7. Resources Required

The resources required to implement and use this evaluation method were determined when the method was tested. The following summarizes the resources that were required during the PFC project analysis.

6.7.1. Time Commitment

The major portion of time required to apply the method was in collecting the data for the financial and qualitative assessments. Since the PFC project was already being evaluated by a PFC team using Intel's current process, much of the data required by the method had already been captured. Therefore, it was a matter of obtaining the required information that was missing. The missing information was determined to be the costs associated with disposal and post-disposal. Most of the qualitative data was either obtained through supplier quotations or through individuals on the PFC decision-making team.

Approximately 40 hours were required to gather and assess the three options for the PFC project using the method. This included the level of effort that was required to advance up the learning curve, to obtain the missing data, and to perform the assessment.

Ideally, with all the data available, using the method should take approximately four to five hours. Using the computerized program created by the author can further decrease this effort.

6.7.2. Level of Difficulty and Effort

For the most part, the method is not difficult to understand or to use. The most difficult aspect is the effort required to obtain the data. The analysis portion is self-explanatory and easy to perform. It is even easier when using the computerized program.

7. Recommendations for Methodology Proliferation

One of the key challenges faced when testing this method at Intel was obtaining acceptance by the users of the method. This purpose of this chapter is to provide some insight into how to successfully implement this type of method based on the Intel experience.

There are two critical areas that should be addressed when integrating this method into current business processes. First, an understanding of how the method supports the business strategy should be ascertained, and second, an implementation strategy should be developed that is supported by all the key stakeholders. Addressing these areas early in the implementation process will increase the probability of successful implementation.

7.1. Overall Business Strategy

It is critical that the key stakeholders understand how the new method will support the overall business strategy. Stakeholder support is essential to successful implementation, otherwise efforts will be diverted to satisfying the key players' concerns versus implementing the method.

To implement any EHS strategy or method requires a clear vision of how environmental initiatives are supported by the overall business. At a minimum, this requires top management support of these initiatives so that others see the criticality of EHS issues. The probability of success can be increased if additional initiatives are implemented. These include integrating EHS into the business culture, setting long and short term environment, health and safety goals, developing an EHS organization, and providing incentives to integrate EHS into decisions about product and process designs.

7.2. Implementation Strategy

Successful implementation of the evaluation method does not require that EHS initiatives already be incorporated into the business culture. Although, if an EHS structure is already established, incorporating the method into current processes can be easier. The following are recommendations on how to successfully implement the evaluation method.

7.2.1. Upper Management Support

Upper management support is critical to the successful implementation of any project. Their lead in EHS initiatives will provide the incentive for others to support it as well. The endorsements received from upper management are essential in the execution of this method since it can require many procedures and processes to be changed.

7.2.2. Organizational "Buy-In"

Although upper management support is critical, the continued success of the program relies on the participation of the organizations involved in the process. There are a variety of ways to obtain the key players' support. The following sections outline some strategies to consider.

7.2.2.1.Education

One of the top reasons employees do not support new initiatives is the lack of understanding a project. Therefore, education early on in the process will make employees aware of the mission and goals of the project.

An organizational concern that may need to be addressed deals with the finance organization. The financial section of the method takes a different approach than currently used by most financial and accounting organizations. The primary difference is that the method includes EHS costs in the financial analysis. This is a paradigm shift for most typical finance organizations. Finance, and potentially other organizations, need to be educated about the benefits of assessing a project using a method that captures *all* the costs. This ensures that any additional costs that are associated with disposal, post-disposal, reuse, recycle and EHS efforts are considered up-front and not discovered after implementation. More information on the benefits of this approach can be found in Daren Dance's article, "Applications of Cost of Ownership to Environment, Safety and Health" written for the 1996 IEEE IEMT Symposium.

7.2.2.2.Integration into current processes

It is understood that not all companies are at the same stage concerning environmental, safety and health initiatives. For those that are further along, the method can most likely be integrated into current evaluation processes, thereby avoiding the "reinvent the wheel" syndrome. This can lead to additional organizational support because (1)current processes are being used that are performing well and (2) it can reduce the skepticism that comes along with making changes and implementing new initiatives.

Any current evaluation process that will be affected by this method should be reviewed to determine the level of impact, if any, to processes, labor and operations. Procedures that are currently functioning appropriately should be integrated into the method process when appropriate. For instance, the current health and safety evaluation process used at Intel was comprehensive and integrated across multiple sites. An assessment was done by the team on Intel's health and safety process to determine whether the process met the requirements of the data collection portion of the method. Intel's process did meet the method's requirements and was therefore integrated into the method.

7.2.2.3. Test on A Project

One of the key strategies to winning support from skeptics about a new method is to test it on a sample project. Evaluate a sample project using the current process as well as the method. This will provide comparison data on the effectiveness of the method. The PFC project was currently in the process of being evaluated using Intel's current method. The methodology development team used the results from both evaluations to convince management of the benefits of using the method. Future and/or potential projects could also be used to test the method. If neither of these types of projects are available, then the method can be tested on a past project that already has been evaluated.[26]

Along with providing a first hand look at the results of this method, testing a project also provides insight into those areas of the current method that can be improved. If stakeholders are part of the review and improvement process, they will more likely accept it.

7.2.3. Training of Key Personnel and Documentation

Training should be provided for of all key functional areas involved in the process. It is critical to provide this training prior to implementing the method. The training should also include an awareness of overall environmental, health and safety issues so users understand that their efforts are important.

Clear documentation of the process is also essential. This documentation will be used not only as a reference for current users, but also as a training reference for future users. Documentation also serves as proof that the evaluation method is being used to evaluate projects that have an impact on the environment, and the health and safety of the individuals dealing with the project.

If a company's strategy is to integrate EHS decisions into the workplace, then the optimal time to train personnel on the use of the method is during new hire orientation. New hires should be made aware of

[26] A word of caution, it may be more difficult to test past projects since support from the initial evaluation team may no longer be available.

the method, the importance of EHS issues; the hierarchy of decisions concerning EHS, and the procedures to report concerns or generate ideas about EHS.

7.2.4. Internal Infrastructure

An understanding of how the method "fits" into the current infrastructure is essential prior to implementation. A documented list of contact people should be provided to all the key personnel during their training.

7.2.5. Communication between Sites

If the method will be implemented across multiple sites, then it is critical to establish communication links between all the sites. This ensures that all sites are made aware of the proposed change and are part of the evaluation.

In addition, procedures should be put in place to ensure that updates made to the method will be communicated to all parties involved. This can be done through documentation control, weekly face-to-face meetings or notification procedures.

7.2.6. Measurement System

Prior to implementation, a measurement system should be put in place to measure the effectiveness of the method. This can be done by measuring a variety of factors such as the amount of costs that would have been ignored through the original process but were discovered using the method's financial approach. Additional metrics that can be considered are the number of projects determined to be environmentally unsafe and the cycle time required to perform assessments.

A feedback system on the overall effectiveness of the method should also be developed. Feedback is critical in the effective use of the method and provides opportunities for continuous improvement.

7.2.7. Supply Chain Impact

The entire supply chain should be reviewed to determine how the new method will affect the various areas, both negatively and positively. The following are potential areas of the supply chain to address.

7.2.7.1.Suppliers

The method focuses not only on the costs and functionality of a project, but also on the proposed project's environmental impact, and on the supplier's reputation. It is therefore important to educate suppliers about the evaluation process and to work with them to develop environmentally benign products that would pass the method assessment.

7.2.7.2.Product and Process Design

Product and process designers should also be integrated into the method. If products and processes are not designed to be more environmentally sustainable, approval will be difficult using the method. This could potentially delay the release of new products to the market.

7.2.7.3.External Customers

It may also be important to make external customers and regulators aware of the assessment method. This will increase their awareness of the corporation's efforts to produce environmentally benign products and could produce positive results for the company in the future.

8. Applicability to Other Industries

Although this method was prepared specifically for Intel and emphasized its use in the semiconductor industry, it can be modified to be applicable to any industry. The following sections suggest the areas that should be addressed to make the method applicable to other industries.

8.1. Project Drivers

The project drivers are a list of areas that the company thinks are important reasons to initiate projects. A company would have to review the list to determine the hierarchy of the drivers in their decision making process.

8.2. Rejection Criteria

The pre-screen rejection criteria pertains to the semiconductor industry. These criteria need to be reviewed and changed to be applicable other industries.

8.3. Data Collection

There are nine areas of data collection. Of the nine, it is recommended that at least the following two be reviewed. Others can be reviewed as well.

Manufacturing Impact

The manufacturing areas that are critical to a company or industry need to be determined. For example, yield is critical in the semiconductor industry.

Resource Consumption

Other resources along with water and energy may be important to other industries and should be considered during the evaluation.

8.4. Matrix Assessment

The chart of values assigned to the data collection responses (see Exhibit 2) in the analysis should be updated to reflect the importance of the impact of each question to the company or industry.

8.5. Financial Assessment

The list of costs associated with each of the life cycle phases should be reviewed for applicability to the other industries.

9. Conclusions

In today's business environment, design, process and operations decisions need to consider EHS issues. The method described in this thesis attempts to provide a systematic approach at assessing projects and to ensure that decisions are made considering *all* the relevant data.. The model developed is a worthwhile tool for companies to use to assess projects, not only based on the costs and savings throughout a project's *entire* life cycle, but also on a variety of qualitative issues such as manufacturing, health and safety, environment, and supplier capabilities.

9.1. Usefulness of Method

Testing the method at Intel on the PFC project sparked strong interest, both at the site level and at corporate. The main attributes of the method that were noted to be worthwhile by Intel were:

- The consistency of the method in assessing projects and the ability of the method to be easily integrated across various Intel sites.
- The ease of use provided by the computer interface making it simpler for users of the model to input data and assess projects.
- The consideration of life cycle costs and qualitative factors in the method.

There were also some problems associated with the method. The main concerns with the method were:

- The subjectivity associated with the assigning decision weights and with determining the factor ranks in the cross reference matrix.
- The possibility of inconsistent data collected for the phases of the financial assessment.
- The ability to manipulate the results of the matrix assessment.

Although Intel is aware of these issues, they have decided to continue to test the method on future projects. Some of the concerns associated with the method could potentially be overcome through training, enforcement of procedures, and discipline.

Although there are some concerns with the model, overall it provides a useful tool in assessing projects that have an impact on the environment, health or safety. The method is not intended to make the final decision on a project. Since companies, industries, and organizations have different strategies in making decisions, the method provides the information required to make a final decision. The intent of the method was first to consider the environment, health and safety issues in evaluating a project and second, to capture and present the pertinent data required to make a final decision. The combination of the matrix analysis of the qualitative factors, the NPV calculation on life cycle costs, and the bulls eye summary, provides management with the key pieces of information to make educated decisions.

9.2. *Future Suggestions*

The CARRI model created by SEMATECH can be a very useful tool to evaluate projects where the EHS stakes are high and where the analysis time is not a critical issue. If, in the future, CARRI's databases are completed and the requirements for maintaining the data are not so labor intensive, then CARRI could be a useful addition to the method to assess the health and safety concerns associated with product, process, or chemical changes.

Exhibit 1 - Detailed Process Flow of Method

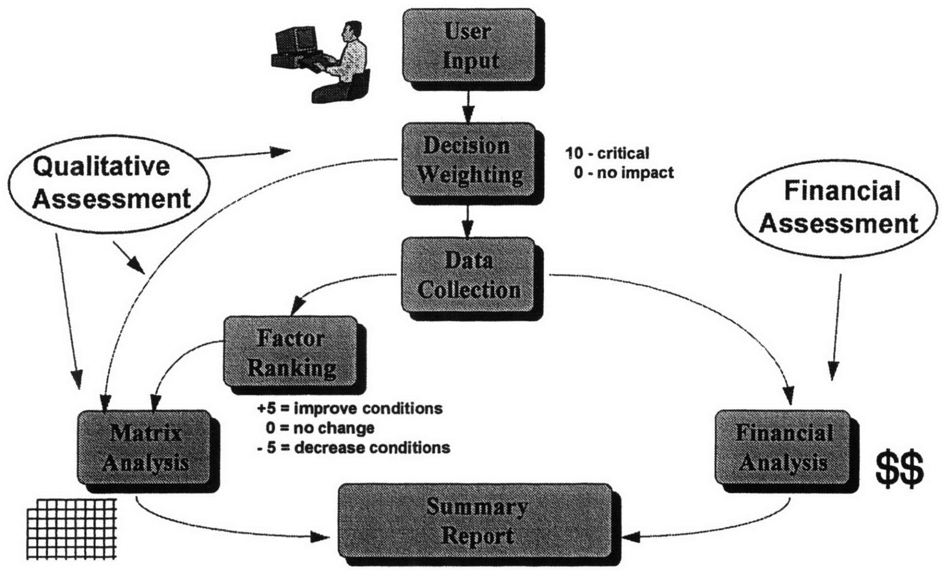

Exhibit 2 - Chart of Response Values

			Possible Responses													
Factor	**Questions**		**Yes**	**No**	**N/A**	**High**	**Med**	**Low**	**Large**	**Med**	**Small**	**Inc**	**Dec**	**< 1day**	**> 1day**	**No Impact**
Air Impact	Q1	Uses ODCs	-5	5	X											
	Q2	Low Odor Tolerance	-5	5	X											
	Q3	GW Compounds	X	5	X											
	Q3A	- > 1995 emission levels	-5	-3	X											
	Q4	Use/Create PFCs			X							-5	5			
	Q5	Use of HAPS			X							-5	5			
	Q6	Increase in regulated air pollutants	-5	5	X											
	Q7	Use of VOCs			X							-5	5			
System/Supplier Capabilities	Q1	Supplier Data Available	5	-5	X											
	Q2	Supplier Certified	5	-5	X											
	Q3	Chemical Use	X	5	X											
	Q3A	- Is it a new chemical?	-5	3	X											
	Q4	Is the supplier easy to work with?	5	-5	X											
	Q5	Is system tested in industry?	5	-5	X											
	Q6	Supplier expertise (H/M/L)			-5	5	3	-3								
	Q7	System meets requirements	5	-5	X											
Resource Consumption	Q1	Water Consumption (Inc/Dec)			X							-5	5			
	Q2	Transfer Waste Streams?	X	5	X											
	Q2A	- Increase diff. waste stream?			X							-5	0			
	Q3	Energy Use (Inc/Dec)			X							-5	5			
Liquid Waste Stream	Q1	Physical change in exhaust configuration or flow rate	X	5	X											
	Q1A	- Permit Change	-5	-3												
	Q2	Physical change in drain system or flow rate.	X	5	X											
	Q2A	- Permit Change	-5	-3												
	Q3	Change in composition or concentration of continuents in exhausts.	X	5												
	Q3A	- Permit Change	-5	-3												
	Q4	Change in composition or concentration ofconstiuents in liquid wastes or waste by products.	X	5												
	Q4A	- Permit Change	-5	-3												
	Q5	Inc/Dec Hazardous Waste			X							-5	5			
Solid Waste Stream	Q1	Physical change in exhaust configuration or flow rate	X	5	X											
	Q1A	- Permit Change	-5	-3												
	Q2	Physical change in drain system or flow rate.	X	5	X											
	Q2A	- Permit Change	-5	-3												
	Q3	Change in composition or concentration of continuents in exhausts.	X	5												
	Q3A	- Permit Change	-5	-3												
	Q4	Change in composition or concentration of constiuents in liquid wastes or waste by products.	X	5												
	Q4A	- Permit Change	-5	-3												
	Q5	Inc/Dec Hazardous Waste			X							-5	5			

Exhibit 2 - Chart of Response Values (continued)

Factor		Questions	Yes	No	N/A	High	Med	Low	Large	Med	Small	Inc	Dec	< 1day	> 1day	No Impact
Manufacturing Impact	Q1	Yield Impact			X							5	-5			
	Q2	Impacts production for installation.	X	5	X											
	Q2A	- If YES, Requires Equipment shut-down	X	5	X											
	Q2B	- If YES, Length of impact (<> 1 Day)			X									-3	-5	0
	Q3	Probability of impact to prod'n due to tool malfunct. (H/M/L)				-5	-3	-1								5
	Q4	Impact to prod'n throughput or equip. availability (Inc/Dec)			X							5	-5			
Transportation/ Logistics Issues	Q1	Tracking/Reporting Effort (Inc/Dec)			X							-5	5			
	Q2	Additional Controls	-5	5	X											
	Q3	Special Container Requirements	-5	5	X											
Health and Safety Issues	Q1	Uses Ethylene based glycol ethers that are reproductive hazards	-5	5	X											
	Q2	Uses arsine	-5	5	X											
	Q3	Uses Carcinogen	-5	5	X											
	Q4	Uses potential carcinogen — eg.	-5	5	X											
		- Tricholoroethylene														
		- Carbon Tetrachloride (ODS)														
		- Chloroform														
	Q5	Uses a reproductive toxin	-5	5	X											
	Q6	Uses a Toxic Chemicals	X	5	X											
	Q6A	If *YES* LD50 (mg/kg) 4 hr. LC50 (ppm)														
		extreme 1 <10	-5													
		highly 1-50 10-100	-4													
		moderate 50-500 100-1,000	-3													
		slight 500-5,000 1,000-10,000	-2													
		non-toxic 5,000-15000 10,000-100,000	X													
		Anticipated Qty to be used approaches threshold dose for toxicity	-4													
	Q7	Other Potential impact to harm employees	-5	5	X											
	Q8	Uses highly flammable substances	-5	5	X											
Installation/ Operation Issues	Q1	How much floor space is required (L/M/S)			X				-5	-3	-1					
	Q2	Is space available?	5	-5	X											
	Q3	Additional labor req'd for install/operation	-5	5	X											

Exhibit 3 - Example of Summary Report

PROJECT SUMMARY REPORT

Project #:

Project Title:

Scope of Project:

Drivers of Project:

Project Impact on Company Pollution Prevention Efforts:

- ☐ Project will Prevent or Reduce Waste
- ☐ Project will Reuse or Recycle Waste
- ☐ Project will Treat or Abate Waste

Information Required prior to making a Decision (Note checked boxes):

☐ **Expected implementation across multiple sites. Information MUST be transferred and approved by other sites.**

*** **Requires EHS Action:** ***

Air/Emissions:

- ☐ **Review PFC use with EHS and document.**
- ☐ **Unsure if ODC's are used. Confirm with EHS.**
- ☐ **HAPS are INCREASED. EHS must review for permit and capacity implications.**
- ☐ **VOCs are INCREASED. EHS must review for permit and capacity implications.**
- ☐ **Review INCREASE in water consumption and evaluate implications.**
- ☐ **Contact EHS to determine odor threshold.**
- ☐ **Chemical has LOW odor tolerance. Contact EHS to determine how it will be controlled.**
- ☐ **Contact EHS to determine if global warming compounds are used.**
- ☐ **Notify the SCC about the potential increase in the following air pollutants with this project.**
- ☐ **Notify EHS about use of global warming compounds.**

Liquid Waste Streams

- ☐ **Drain configuration is changed and impacts permit conditions. Review of impact.**
- ☐ **Drain configuration is changed . Review for system capacity implications.**
- ☐ **Review change in current composition and/or concentration in the exhausts.**
- ☐ **Review change in the composition and/or concentration of constituents in the liquid wastes.**
- ☐ **Review INCREASE in hazardous waste for disposal and system capacity implications.**
- ☐ **Exhaust configuration or flow rate is changed and impacts permit conditions. Review for impact.**
- ☐ **Exhaust configuration or flow rate is changed. Review for system capacity implications.**

Solid Waste Streams

- ☐ **Drain configuration is changed and impacts permit conditions. Review of impact.**
- ☐ **Drain configuration is changed . Review for system capacity implications.**
- ☐ **Review change in current composition and/or concentration in the exhausts.**
- ☐ **Review change in the composition and/or concentration of constituents in the solid wastes.**
- ☐ **Review INCREASE in hazardous waste for disposal and system capacity implications.**
- ☐ **Exhaust configuration or flow rate is changed and impacts permit conditions. Review for impact.**
- ☐ **Exhaust configuration or flow rate is changed. Review for system capacity implications.**

Resource Consumption

- ☐ **Review INCREASE in energy use and evaluate implications.**
- ☐ **Review change in waste streams.**

Exhibit 3 - Summary Report Example (continued)

*** ***Additional Action Items:*** ***

- ☐ Supplier not Approved. Obtain Approval from Corporate Acquisition Group
- ☐ Chemical not approved. Chemical Approval Form MUST be completed and submitted to EHS for approval .

Benefits

- ☐ Solid Hazardous waste DECREASED. Document decrease and notify EHS.
- ☐ VOCs are DECREASED. Document decrease and notify EHS.
- ☐ HAPS are DECREASED. Document decrease and notify EHS.
- ☐ Energy use DECREASED. Document decrease and notify EHS.
- ☐ Liquid Hazardous waste DECREASED. Document decrease and notify EHS.
- ☐ Water consumption DECREASED. Document decrease and notify EHS.
- ☐ Project IMPROVES yield.
- ☐ Project/change INCREASES production throughput and/or equipment availability.
- ☐ Low probability that production will be impacted if equip. malfunctions.

Concerns:

- ☐ Implementation/Installation of Project will impact production.
- ☐ HIGH probability that production will be impacted if equip. malfunctions.
- ☐ Project will impact production to install equipment
- ☐ Additional floor space is required for installation. Need to check resource and financial impact
- ☐ Additional resources are required to operate, maintain and control system.
- ☐ Increased chemical tracking and reporting is required.
- ☐ Additional controls (hardware/software) will required:

Financial Assessment:

The Net Present Cost of this project is:

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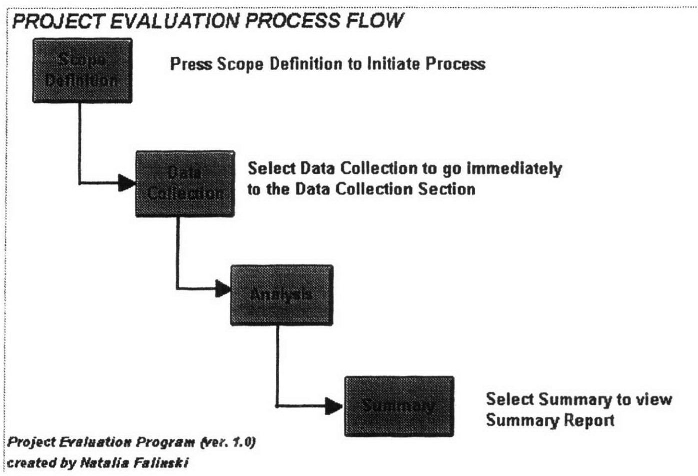
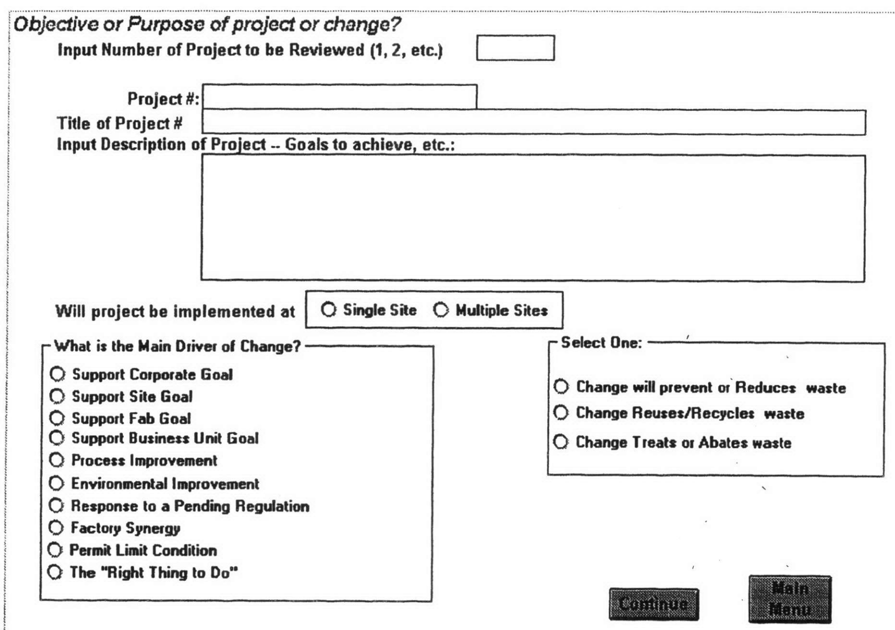
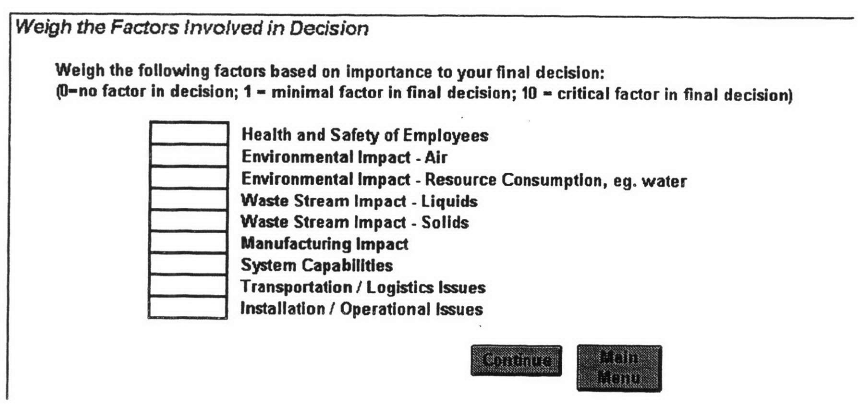
Appendix A

Sequential Screens from Computerized Methodology

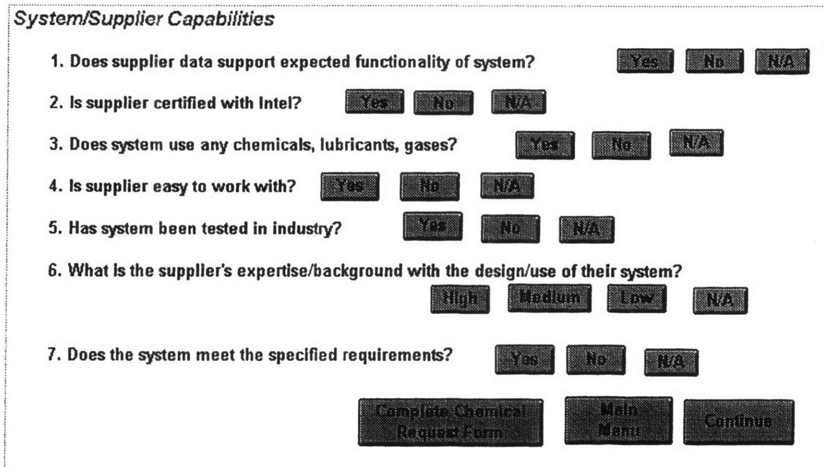
Scope Definition - The program allows the user to input information on the objective of the project and to assign the decision weights to the factors.







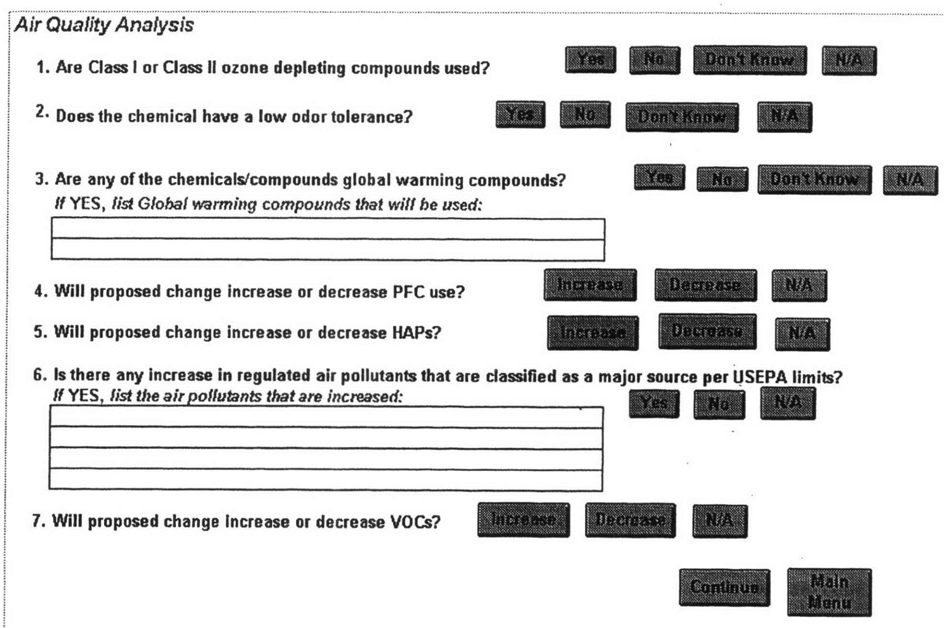
Data Collection - The program prompts the user to answer questions for each of the nine factors. Based upon the responses, the program calculates the average rank for each phase.



System/Supplier Capabilities

1. Does supplier data support expected functionality of system? Yes No N/A
2. Is supplier certified with Intel? Yes No N/A
3. Does system use any chemicals, lubricants, gases? Yes No N/A
4. Is supplier easy to work with? Yes No N/A
5. Has system been tested in industry? Yes No N/A
6. What is the supplier's expertise/background with the design/use of their system? High Medium Low N/A
7. Does the system meet the specified requirements? Yes No N/A

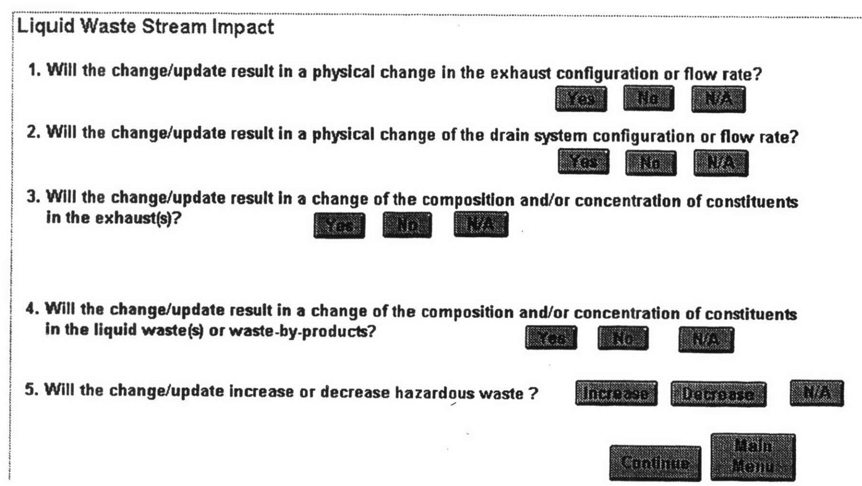
Complete Chemical Request Form | Main Menu | Continue



Air Quality Analysis

1. Are Class I or Class II ozone depleting compounds used? Yes No Don't Know N/A
2. Does the chemical have a low odor tolerance? Yes No Don't Know N/A
3. Are any of the chemicals/compounds global warming compounds? Yes No Don't Know N/A
   If YES, list Global warming compounds that will be used:
4. Will proposed change increase or decrease PFC use? Increase Decrease N/A
5. Will proposed change increase or decrease HAPs? Increase Decrease N/A
6. Is there any increase in regulated air pollutants that are classified as a major source per USEPA limits? Yes No N/A
   If YES, list the air pollutants that are increased:
7. Will proposed change increase or decrease VOCs? Increase Decrease N/A

Continue | Main Menu



Liquid Waste Stream Impact

1. Will the change/update result in a physical change in the exhaust configuration or flow rate? Yes No N/A
2. Will the change/update result in a physical change of the drain system configuration or flow rate? Yes No N/A
3. Will the change/update result in a change of the composition and/or concentration of constituents in the exhaust(s)? Yes No N/A
4. Will the change/update result in a change of the composition and/or concentration of constituents in the liquid waste(s) or waste-by-products? Yes No N/A
5. Will the change/update increase or decrease hazardous waste ? Increase Decrease N/A

Continue | Main Menu

Solid Waste Stream Impact

1. Will the change/update result in a physical change in the exhaust configuration or flow rate?
   Yes No N/A
2. Will the change/update result in a physical change of the drain system configuration or flow rate?
   Yes No N/A
3. Will the change/update result in a change of the composition and/or concentration of constituents in the exhaust(s)? Yes No N/A
4. Will the change/update result in a change of the composition and/or concentration of constituents in the liquid waste(s) or waste-by-products? Yes No N/A
5. Will the change/update increase or decrease hazardous waste ? Increase Decrease N/A

Continue | Main Menu

Resource Consumption Analysis

1. Will change/update increase or decrease water consumption? Increase Decrease N/A
2. Will change/update transfer waste streams? Yes No N/A

2a. How is change in waste stream impacted? Increase Decrease No Impact

3. Will change/update increase or decrease energy use? Increase Decrease N/A

Continue | Main Menu

Manufacturing Impact

1. How will change affect yield? Improve Yield Degrade Yield N/A
   Explain:
2. Will change impact production for installation? Yes No N/A
   How?
3. Is the probability of impacting production HIGH or LOW if tool or equipment malfunctions?
   Ex. HIGH if tool doesn't have a buffer between it and process tool
   LOW if tool has a buffer between it and the process tool. High Low N/A
4. Once change is incorporated, how will it impact production throughput and/or equipment availability?
   Increase Decrease No Impact N/A
   Explain:

Continue | Main Menu

Transportation / Logistics Issues

1. **Will proposed change increase/decrease chemical tracking and/or reporting?**

   Increase | Decrease | N/A

2. **Will proposed change require additional controls (hardware/software)?** Yes | No | N/A

   If YES, list type(s) of control(s) below:

3. **Are there special container requirements for transportation?** Yes | No | N/A

   Continue | Main Menu

Installation / Operations Impact

1. **How much floor space will be required?** Large | Medium | Small | N/A

2. **Is space available?** Yes | No | N/A

3. **Will the operation and maintenance of the proposed systems require additional resources to operate, maintain and control?**

   Yes | No | N/A

   Continue | Main Menu

Sample of Rank Calculation

Air

Q1	5
Q2	5
Q3	5
Q3A	X
Q4	5
Q5	5
Q6	5
Q7	5
Total N/A's	**1**
Avg	**5.0**

System Capabilities

Q1	5
Q2	5
Q3	X
Q3A	3
Q4	5
Q5	5
Q6	5
Q7	5
Total N/A's	**1**
Avg	**4.7**

Resource Conservation

Q1	5
Q2	5
Q2A	0
Q3	5
Total N/A's	**0**
Avg	**3.8**

Liquid Waste

Q1	5
Q2	5
Q3	5
Q4	5
Q5	5
Total N/A's	**0**
Avg	**-5.0**

Solid Waste

Q1	X
Q2	X
Q3	5
Q4	5
Q5	5
Total N/A's	**2**
Avg	**5.0**

Manufacturing Impact

Q1	-5
Q2	5
Q2A	X
Q2B	-3
Q3	-3
Q4	5
Total N/A's	**1**
Avg	**-0.3**

Transportation/Logistics

Q1	5
Q2	5
Q3	5
Total N/A's	**0**
Avg	**5**

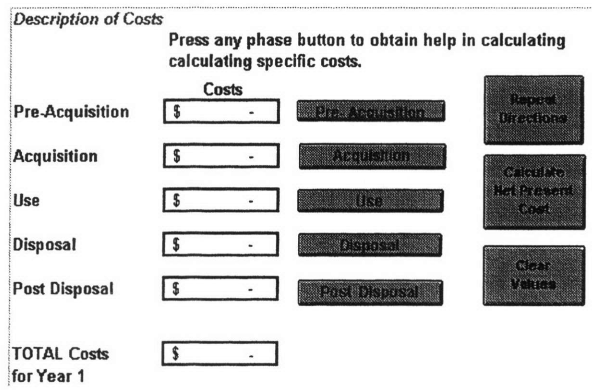
Health and Safety

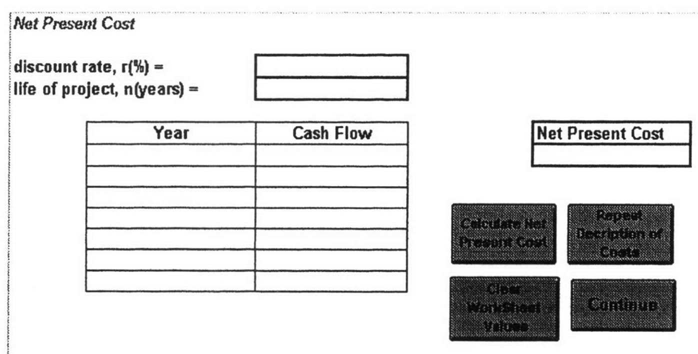
Q1	X
Q2	5
Q3	-5
Q4	5
Q5	5
Q6	X
Q6A	X
Q7	-5
Q8	5
Total N/A's	**3**
Avg	**1.7**

Installation/Operation

Q1	-1
Q2	5
Q3	5
Total N/A's	**0**
Avg	**3**

Financial Assessment - The program allows the user to input the costs associated with each of the five life-cycle phases, automatically totals the costs for each phase and then calculates the NPV for the project





Summary - A summary report is then generated similar to the report shown in Exhibit 3.

Appendix B

List of Acronyms

CARRI - Computerized Assessment of Relative Risk Impacts
COO - Cost of Ownership
DfE - Design for the Environment
DESH - Design for the Environment, Health and Safety
EHS - Environmental, Health and Safety
EPA - Environmental Protection Agency
ESH - Environmental, Safety and Health
FTDM - Flash Technology Development and Manufacturing
LCA - Life Cycle Analysis
NPV - Net Present Value
P^2 - Pollution Prevention
PFC - Perfluorocompound
SCC - Strategic Chemical Council
SI - Semiconductor Industry
SEMATECH - SEmiconductor MAnufacturing TECHnology - a non-profit R&D consortium of U.S. semiconductor manufacturers.
TQEM - Total Quality Environmental Management
TCOO - Total Cost of Ownership
TD - Technology Development
TMG - Technology and Manufacturing Group
TUWR - Toxic Use and Waste Reduction