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EVALUATION OF HAZARDOUS MATERIAL LIFE CYCLE COST TOOLS FOR USE IN AIR FORCE HAZARDOUS MATERIAL PHARMACIES

THESIS

Rowene J. Resler, Captain, USAF

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Presented to the Faculty of the Graduate School of Engineering

of the Air Force Institute of Technology

In Partial Fulfillment of the Requirements

for the Degree of Master of Science in

Engineering and Environmental Management

Rowene J. Resler, B.S.

Captain, USAF

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Rowene J. Resler

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List of Acronyms and Abbreviations

AFB .... Air Force Base

AFCEE .... Air Force Center for Environmental Excellence

AFMC .... Air Force Materiel Command

AMHM .... Acquisition Management of Hazardous Materials

B&P DSM .... Burley and Phillips Decision Support Model

DAF .... Department of the Air Force

DOD .... Department of Defense

EO .... Executive Order

EPA .... Environmental Protection Agency

EPCRA .... Emergency Planning and Community Right-to Know Act

HAZMAT .... Hazardous Materials Life Cycle Cost Estimator

HazMat PATS .... Hazardous Material Procurement Action Tracking System

HCAS .... Historical Cost Analysis System

HMP .... Hazardous Material Pharmacy

HQ USAF/LG .... Headquarters, United States Air Force, Logistics

LCC .... Life Cycle Cost

NSN .... National Stock Number

ODS .... Ozone Depleting Substance

P2 .... Pollution Prevention

PPIC .... Pollution Prevention Information Clearinghouse

PRO-ACT .... AFCEE's Information Clearinghouse

RACER .... Remedial Action Cost Engineering and Requirements

SPO .... System Program Office

SAF .... Secretary of the Air Force

TRI .... Toxic Release Inventory

Abstract

Recent trends of expanding environmental awareness and a shrinking defense budget challenge Air Force managers faced with the task of reducing environmental impacts associated with current operations. The Air Force has specific environmental goals that the Pollution Prevention Program addresses. One pollution prevention initiative, aimed at reducing operational environmental impact, is the Hazardous Material Pharmacy (HMP) concept.

This research focuses on evaluation of various tools that assist in the selection of hazardous material substitutes. Substitute material consideration is a function of the HMP when a hazardous material is requested for purchase and use in a current base operation. The substitute material decision is complex, involving identification of potential substitutes and then comparison of factors, such as cost, performance, and environmental effects, between the potential substitute and the material being requested. Various tools such as life cycle cost models, databases, and other information services can provide assistance to HMPs making substitution decisions.

The evaluation of tools is based on performance as well as functionality of the tool. Performance of the tool, in providing information to the decision maker, considers categories such as life cycle cost and environmental effects, while tool functionality considers items like ease of use. Although this research specifically addresses HMP requirements, the evaluation can be applied to any operation that makes hazardous material substitution decisions.

EVALUATION OF HAZARDOUS MATERIAL LIFE CYCLE COST TOOLS FOR USE IN AIR FORCE HAZARDOUS MATERIAL PHARMACIES

I. Introduction

General Issue

The recent trends of increasing global environmental awareness and a shrinking defense budget are a constant challenge for Air Force environmental managers who are faced with solving environmental problems with limited resources. Specifically, the cost of managing hazardous materials has drastically increased due to the proliferation of environmental and health regulations. Each of these regulations impose stringent requirements which often add costs at various points along the timeline of hazardous material use, from purchase to disposal. The timeline of use is also referred to as the hazardous material's life cycle.

The total cost of using a material is not only its purchase price, but also includes associated costs such as transportation, handling, monitoring, training, personal protection, medical, emergency response, disposal and potential liability to name a few (Burley and Phillips, 1993:1). Summing these individual costs produces the total Life Cycle Cost (LCC) associated with "cradle to grave" management of the hazardous material. Since there are usually different safety and regulatory requirements depending on the material's hazard characteristics, the LCC of one hazardous material may differ greatly from the LCC of another material.

Organizations interested in being cost-effective must seriously consider what hazardous materials they currently use and consider less costly alternatives. An alternative that costs less over its life cycle is more cost-effective only if the benefits of the alternative are equitable to the benefits of the material currently in use. Finding alternative materials is difficult and LCC calculation is complex, requiring enormous amounts of data. For this reason many models have been developed to calculate LCC of materials and the concept of Life Cycle Assessment has been employed to evaluate hazardous material alternatives.

Life Cycle Assessment (LCA) was introduced over twenty years ago but was only used to a limited extent. In recent years, there has been renewed interest in LCA because of the increased regulation and associated costs of hazardous materials. LCA methodology is a tool developed for and promulgated by the EPA to evaluate the environmental consequences of a product, process or material across it's entire life cycle (Vigon and others, 1993:1). Life cycle consideration was first used by the government in procuring weapon systems (Aldrich, 1993:56). In the Air Force, a 1986 Scientific Advisory Board found the LCC of hazardous materials were not being adequately addressed in the selection of hazardous materials in weapon system acquisition (Burley and Phillips, 1993:2). To address this concern, the Acquisition Management of Hazardous Materials Program (AMHM) was established.

The objective of the AMHM Program is to create an oversight process that integrates LCC considerations for hazardous materials in the system acquisition process (Burley and Phillips, 1993:3). Unfortunately, it does not consider non-weapon system operations such as Civil Engineer, Transportation, and Supply which also use hazardous materials in their daily operations. For example, of the top three hazardous material types used in quantity at Wright-Patterson Air Force Base (AFB), about half are research laboratory chemicals related to acquisition, while the other half are typical non-weapon system materials such as paints, stains, adhesives, and solvents (Robinson, 1996). The Air Force's Pollution Prevention Program addresses minimization of hazardous materials in weapon systems as well as in other operations across the base.

The aim of Pollution Prevention (P2) is to reduce or eliminate the use of hazardous materials and pollutant releases into the environment. Hazardous material use by itself can lead to harmful releases, so minimizing use also limits potential releases. The Air Force established reduction goals for hazardous material purchases, hazardous and solid waste disposal, and energy use (AFCEE, 1994:Ch1,1-2). To help meet the goals, the Air Force adopted a Navy concept of single point base-wide control of hazardous materials and called the initiative a Hazardous Material Pharmacy (HMP) due to its similarity with control of medication at hospital pharmacies. The purpose of a HMP is to use a single point of control to minimize and track the ordering, storage, distribution, use, and disposal of all hazardous materials on base (AFCEE, 1994:Ch4,2-3; HQ USAF/LG, 1995:3-5).

Having this tight control documented on an automated system provides visibility of all hazardous materials on base and allows for accurate real-time information with which decisions can be made. For example, if a material is requested for purchase, a quick check of the system may reveal that the material is already available as an excess from another operation, thus avoiding the purchase. Since stockpiles of material will be minimized or eliminated, shelf-life expiration becomes less of a problem, reducing the amount of disposal required. The HMP operation procedures aim to control problems associated with shelf-life expiration, environmental and occupational health and safety risks, safe and secure storage requirements, disposal and liability costs, and tracking and reporting requirements (HQ USAF/LG, 1995:9).

When hazardous materials are requested, policy states that one function of the HMP is to identify material substitutes which minimize impact on worker safety, health, and the environment, yet still perform the task. During the purchase request approval, the hazardous material's life cycle cost should be taken into account. Both the substitute identification and life cycle cost calculation tasks are complex, requiring much data and expertise. The pharmacy staff is typically composed of supply, biomedical, safety, and environmental personnel. Manning equivalent to a minimum of three full time positions is recommended, consisting of a mix of the above specialties (HQ USAF/LG, 1995:16-17). Typically, the staff does not have the time, equipment, data or expertise needed to identify material alternatives and perform a LCC calculation for all hazardous material purchases (Rindahl, 1996; Moody, 1996). The HMP computer systems currently in use that track the hazardous materials on base do not include a tool to calculate LCC to evaluate substitute material alternatives. The systems just save the material purchase cost and the process to which it was issued (Davis, 1996; Nelson, 1996).

Problem Statement

Hazardous Material Pharmacies (HMP) are charged with identifying substitutes and calculating the life cycle costs for all hazardous material purchases, which requires much time and availability of data. Pharmacy personnel do not perform this task completely for all hazardous material purchases due to time and data limitations. The current computer systems in use for HMP tracking of hazardous materials could overcome the limitations if they incorporate a material substitution module that provides a LCC model and information database. An evaluation of existing tools, including life cycle cost models, databases, and other information services, is needed to select or suggest a framework for an appropriate tool to assist with hazardous material purchasing decisions in the HMP.

Research Objectives

The objective of this thesis is to develop decision criteria for selecting a tool and to evaluate life cycle cost tools against the criteria for use in an Air Force Hazardous Materials Pharmacy. The aim is to find a tool to improve a pharmacy's material purchasing decisions by making appropriate information available in a timely manner. The tool selection criteria focus on Air Force guidance and the evaluation indicates usefulness of the tools. To develop a research framework, the following three research questions were established:

1. What criteria should be used in selecting tools to be considered able to contribute to the pharmacy requirement?
2. What tools are available to meet the functional requirement of hazardous material substitution using life cycle costing?
3. How do the tools found measure up to the selection criteria, and what improvements, if any, are suggested?

Scope and Limitations

The research scope is confined to Life Cycle Cost and similar total cost approaches for hazardous material cost estimating because of Air Force guidance to consider total cost. The research contemplates calculation methods and applicability of existing cost models, substitution decision information, ease of use, and the model's breadth of application. For instance, tools which incorporate computerized data sources to update cost components easily and which include data on new alternative materials will be noted. The range of tools evaluated includes any cost model or database that could assist with hazardous material substitution decisions that was identified by literature search or interviews. The limited number of tools that were mentioned in peer reviewed literature and lack of one definitive expert to interview on available tools limits the confidence level that this effort found a representative sample of the tools currently in use.

II. Background

Chapter Overview

This chapter presents the background of actions made, policies formed, and laws passed concerning the basis for hazardous material substitution decisions. The chapter begins with a review of the literature concerning life cycle cost use in the U.S. Air Force (USAF), the Pollution Prevention program, and the inventory controls instituted with the Hazardous Material Pharmacy (HMP) concept. During discussion of the HMP, the task of purchasing control for hazardous materials is detailed, to include the subtask of selecting less hazardous substitutes for hazardous materials being requested. If adequate life cycle costing tools for comparing material alternatives exist, they could be instrumental for HMPs to assist in a timely substitute decision. The substitution decision as it is discussed in literature is briefly presented to define the broad scope and difficult elements involved in the decision. Literature on decision analysis (DA) provides guidance for making hard decisions when faced with various uncertainties. The DA methodology is presented as it is used to structure this complex problem.

Life Cycle Cost in the USAF

First, definition of the term Life Cycle Cost will be explored. In the Environmental Protection Agency's (EPA) Life Cycle Assessment guidance, the life cycle concept is referred to as "cradle to grave" assessment. The effects of a product begin with raw material acquisition, continue through materials manufacture, product fabrication, consumption, and to waste management options of landfilling, incineration, recycling and composting (Vigon and others,1993:1-4). The EPA Life Cycle Design Guidance Manual organizes a product into life cycle stages:

- raw material acquisition
- bulk material processing
- engineered and specialty materials
- production
- manufacturing and assembly
- use and service
- retirement
- disposal (Keoleian and Menerey, 1993:13)

With increased environmental regulation, operational and disposal costs have grown exponentially. The best way to control those increases is to avoid using environmentally controlled products and materials during the system's design and acquisition. Design activities through the definition of requirements may cost 10-15% of all development costs, yet decisions made at this point may contribute 50% to 70% of the costs for the entire system through its life (Keoleian and Menerey, 1993:42).

In the Air Force, LCC use is typically associated with weapon system development, since acquisition is the largest driver of hazardous waste generation. Approximately 90% of military hazardous materials use and hazardous waste generation is associated with development, building, operating and maintaining weapon systems (Morehouse, 1994:150). Many systems, especially aircraft, often remain in the inventory for over 30 years. So, material selections made during system development dictate the required operation and maintenance procedures and affect the environmental impact of the system for the entire 30 years of ownership, unless during that time a material substitute is found and the technical order modified. DOD Instruction 5000.2, which prescribes acquisition procedures, includes a requirement to include life cycle hazardous material considerations in acquisition activities but is not specific about how to accomplish the task (DOD, 1996:Pt4, 7).

In 1986, the USAF Scientific Advisory Board found that the LCCs of hazardous materials were not being adequately addressed in materials selection during the acquisition process. Based on these findings, the board made these three recommendations:

> - Ensure that the top level Air Force Leadership integrate life cycle cost considerations in the weapon system acquisition process.
> - Ensure that appropriate criteria and methods are developed to evaluate environmental and health considerations.
> - Designate the System Program Office (SPO) as the focal point for exercising these considerations and making decisions for the selection of hazardous materials associated with weapon systems.
>
> (Burley and Phillips, 1993:7)

As these ideas were being institutionalized within the DOD, LCC models were being developed and refined. Early LCC models developed in the 1970s being used by the Air Force were found to have several deficiencies and typically only concentrated on a specific portion of the weapon system's life cycle (Twomey, 1991:17). Advances in computer technology during the 1980s enabled the rapid migration of many LCC models from mainframe to microcomputers. Not only did this migration improve the accessibility of LCC models, but it encouraged the proliferation of models as individuals modified generic models to suit their particular preferences and uses (Twomey, 1991:21).

In 1989, DOD Directive 4210.15, was published which stated that DOD agencies must select, use, and manage hazardous materials over their life cycles to incur the lowest cost to protect human health, the environment, and long-term liability (DOD, 1989:1). The Air Force acquisition community contracted with MITRE corporation to conduct a study to make recommendations to reduce the cost of hazardous materials management (Burley and Phillips, 1993:9). Based on the 1991 recommendations, the Air Force developed the Acquisition Management of Hazardous Materials (AMHM) Program.

One of the goals of Acquisition Management of Hazardous Materials (AMHM) is to provide System Program Offices (SPOs) with the tools to make cost-effective choices based on the LCCs of hazardous materials. To do so, the Air Force is providing training and technical support to SPO personnel and developed a LCC model to evaluate hazardous materials at the research phase. The resulting model, Hazardous Materials Life Cycle Estimator (HAZMAT) has been evolving since 1991 and is currently preparing for release in a windows format (West, 1996). This model will be evaluated in chapter four.

The AMHM program focuses primarily on tools for the research level rather than the operations level, where the systems are actually used and maintained. This is so because the operational technical orders are typically determined by the material decisions made during system design. Looking at the overall life impacts of hazardous materials from conception, through use, and to final disposal is the focus of the Pollution Prevention (P2) Program.

Pollution Prevention

Protecting the environment from pollution has previously resulted in laws being passed to limit 'end-of-pipe' releases of pollution and to encourage treatment of the pollutants created. Only in recent years has the US regulatory structure begun to emphasize protection of natural resources by reducing or eliminating the creation of pollution at its source. The effort and research to reduce the use of toxic materials by finding alternative materials and processes that do not create hazards is being encouraged in industry through the realization that millions of dollars can be saved in reduced purchase, compliance, treatment and disposal costs (Roy and Gray, 1992:181-183).

Federal and DOD Implementation. With growing public awareness of environmental incidents and the cost of cleaning them up, the government started to take action. On October 10, 1989, Secretary of Defense Cheney issued a memorandum on environmental policy to the military. He said the "Administration wants the United States to be the world leader in addressing environmental problems, and I want the Department of Defense to be the federal leader in agency environmental compliance and protection." (Morehouse, 1994:150) The policy emphasized integrating and budgeting environmental considerations into activities and operations. The complementing DOD Directive 4210.15, Hazardous Materials Pollution Prevention, defined hazardous materials to be "anything that due to its chemical, physical, or biological nature causes safety, public health, or environmental concerns that result in an elevated level of effort to manage it." (DOD, 1989:6) The directive also instructs the Department of Defense to manage hazardous materials over their life cycles to incur the lowest cost to protect human health, the environment, and long-term liability. Although this policy makes business sense, implementation is an enormously difficult and complex task. Both the art and science of material selection and environmental impact analysis are in their infancy, so program managers with restricted budgets are left with tough decisions between the competing priorities.

In October 1990, Congress passed the Pollution Prevention Act, emphasizing opportunities that exist for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw materials use (HR5931, 1990:2). The new policy statement was needed because existing regulations did not give sufficient credit to reducing pollution at the source. The Act declares a national policy statement for pollution prevention (HR5931, 1990:3). This new policy that prioritizes environmental considerations is known as the pollution prevention hierarchy. The hierarchy is represented in Figure 1 and is the recommended strategy for dealing with pollution (US EPA, 1992:5). It emphasizes source reduction consideration first, followed by recycling, then treatment and finally disposal only as a last resort.

At the top of the hierarchy is the method of prevention or reduction of pollution at the source. To ensure a consistent approach, the term source reduction was defined to mean any practice which, 1) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream...prior to recycling, treatment, or disposal; and 2) reduces the hazards to public health and the environment associated with the release of such substances. The term includes equipment and process modifications, reformulation or redesign, substitution of materials, and improvements in housekeeping, maintenance,

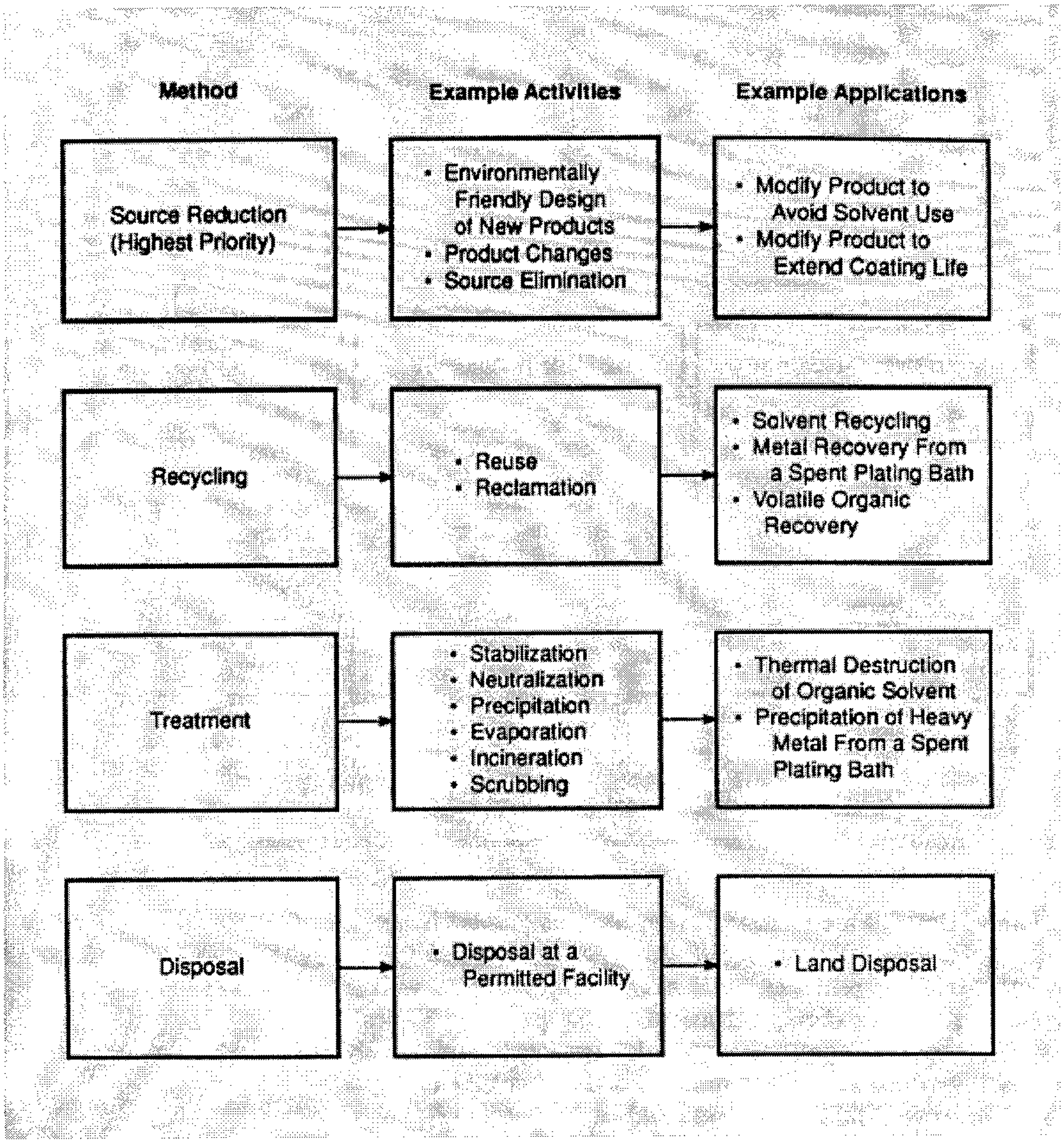

Figure 1: Pollution Prevention Hierarchy (US EPA, 1992:5)

training or inventory control (HR5931, 1990:4). A figurative representation of source reduction methods is at Figure 2 (US EPA, 1992:6). Note that substitution of less toxic chemicals as well as improved operating procedures, material handling, and inventory control are all process changes that are considered source reduction efforts, each of which are discussed later this chapter.

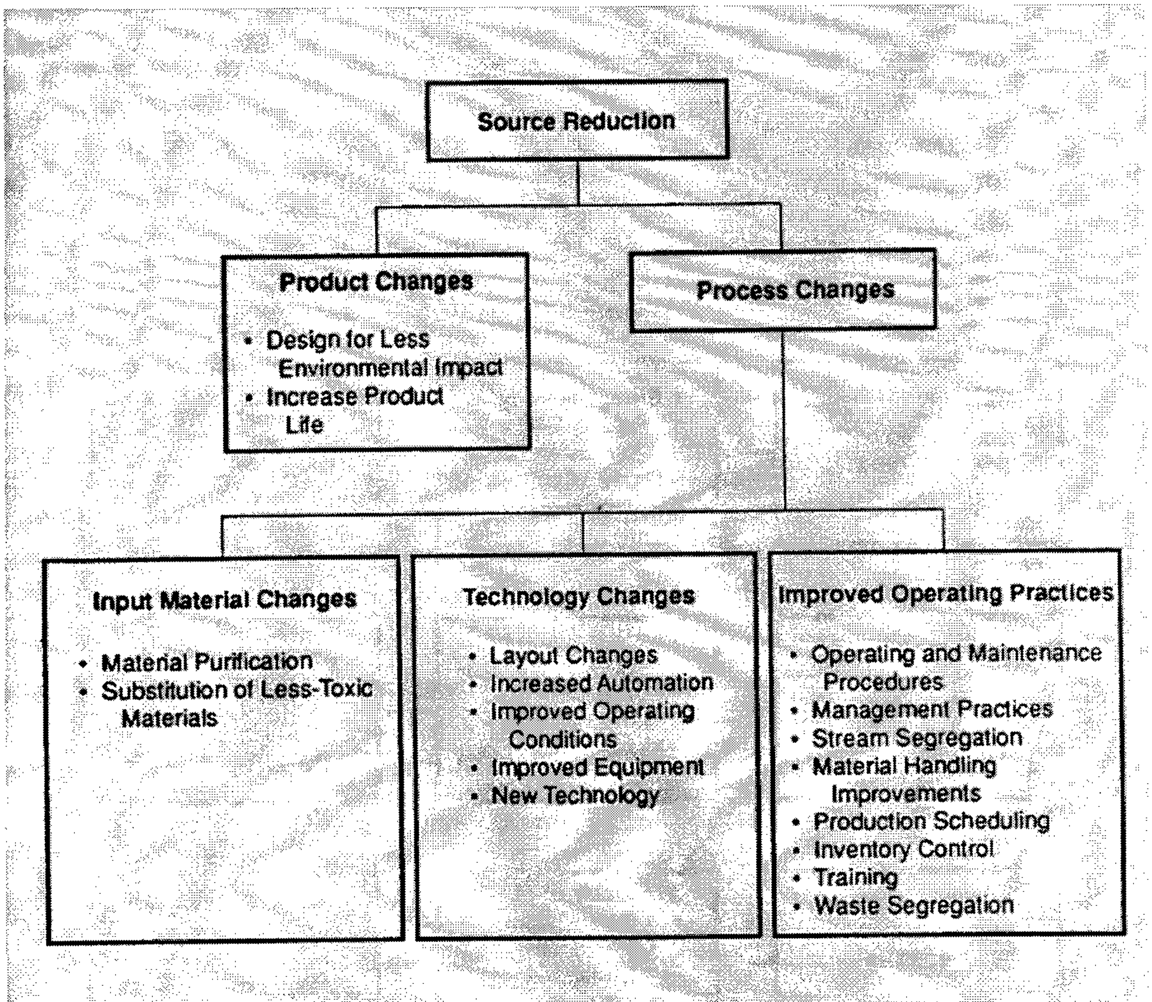

Figure 2. Source Reduction Methods

(US EPA, 1992:6)

Air Force Implementation. On November 13, 1992, Chief of Staff of the Air Force General Merrill A. McPeak and Secretary of the Air Force Donald B. Rice jointly signed a memorandum proposing a comprehensive Pollution Prevention Action Plan. The memo to all major commanders asked for endorsement of specific goals, recommendations, and an estimate of resources to achieve them. An investment strategy was established and the memorandum was formally signed in 1993, establishing the Pollution Prevention Program. The strategy states "The Air Force is committed to preventing future pollution by reducing the use of hazardous materials and releases of pollutants into the environment to as near zero as feasible." (Morehouse, 1994:151)

The Pollution Prevention Action Plan has six objectives:

1) Reduce the use of hazardous materials in all phases of new weapon system acquisition.
2) Reduce the use of hazardous materials in existing weapon systems by changing materials to environmentally preferable alternatives and updating technical orders and specifications.
3) Reduce hazardous materials use and waste generation at Air Force installations and plants.
4 and 5) Acquire the best technologies from industry or develop them internally and share with others.
6) Establish an investment strategy to fund the pollution prevention program.
(Morehouse, 1994:151-152)

It is primarily the third objective that this thesis is concerned with. Because weapon systems are a major part of Air Force pollution issues, most attention on developing tools and improving methods has been directed towards acquisition. Unfortunately, very few efforts have had resources directed specifically at reducing daily hazardous materials use at Air Force installations.

The 1993 Pollution Prevention Action Plan is replaced and updated by the July 1995 Air Force Pollution Prevention Strategy. It includes a vision statement and the following four objectives:

1. Permeate all mission areas with the pollution prevention ethic through comprehensive education, training and awareness.
2. Institutionalize pollution prevention into all phases of the weapon system life cycle.
3. Incorporate pollution prevention in all aspects of installation operations.

4. Develop and transition innovative pollution prevention technologies to the field.

(SAF, 1995)

Just as the preceding action plan, the strategy emphasizes everyday operational concerns in objective three. A specified sub-objective states "minimize or eliminate the use of hazardous materials and ozone depleting substances (ODS) in all activities." One method suggested to accomplish the objective is to implement the hazardous material pharmacy concept of controlling the receipt, repackaging and issue of hazardous material similar to the control over prescription drugs (SAF, 1995).

Hazardous Materials Pharmacy Concept

Finding hazardous material alternatives and changing the related technology is a desired goal that often takes much precious time performing the research. While the effort should continue, it is possible to alter operational material handling practices to bring positive changes in the near term. One such practice with potential is inventory control that is used both by companies and Air Force installations alike.

Industry Implementation. Improved inventory control includes a system of surplus material identification and material tracking. The purpose is to eliminate the "out-of-sight, out-of-mind" mentality that often causes inefficient materials management and excess waste. For example, when stashed away materials are eventually discovered, their shelf-life has often expired. Material tracking systems can help minimize surpluses, spoilage, and missed opportunities for reuse (Callahan and Sciarrotta, 1994:33). The three major sources of waste from poor inventory practices are excess materials, expired or out-of-specification materials, and materials that are no longer needed or used. This costs money directly because the company loses the benefit of using the raw material, has paid for its purchase, handling and storage, and now must pay to dispose of it (McComas, 1995:31).

In 1993, many manufacturing firms had realized the importance of tight inventory controls and were actively involved in Just-In-Time (JIT) management programs. This philosophy seeks to eliminate waste from all internal activities through close coordination between the activity, purchasing, and suppliers. JIT delivers the materials when they are needed in the exact quantity and quality required. This is possible only with improved inventory management practices such as:

- Standardize paints, cleaning agents, oils, etc. within a facility to interchangeable use and reuse.
- Improve inventory control to avoid over-purchase, material spoilage, and material obsolescence due to expired shelf-life.
- Buy in bulk only where practical.
- Centralize all material purchase records to facilitate easy tracking.

(Pojasek, 1993:353)

Other practices also reduce costs and minimize the risks associated with a material inventory. A company may evaluate the risks of each chemical purchased, to include handling precautions and any reporting requirements, to allow comparisons between alternatives. Storage area design is important; keeping frequently used items stored close to the point of issue reduces losses from handling the inventory. Also, dispensing in precise amounts and other materials handling operations should be optimized to generate negligible losses (Pojasek, 1993:353-354).

Air Force Implementation. The Air Force Materiel Command (AFMC) tried the inventory control philosophy at the several major depots in 1989 when starting the Hazardous Material Pharmacy (HMP) concept. A few of the first bases to track all hazardous materials on the installation and control material issue to authorized personnel were Hill AFB Utah, Tinker AFB Oklahoma, McClellan AFB California, and Kelly AFB Texas (Moody, 1996). The main elements as developed by a process action team at Hill AFB, include a Hazardous Material Automated Data Processing System, a dedicated staff, and a dispensing facility to issue materials in the exact quantity. The computer is the heart of the HMP, tracking all purchases, storage locations, material issues, hazard information, work crew authorizations and training records, and generating reports on hazardous material inventory and usage (Nelson, 1996). A potential benefit of pharmacies is the opportunity to interdict the processes that generate hazardous waste by recommending less hazardous, more effective, and/or more economical alternatives to the conventional hazardous materials, alternative processes, and less wasteful shop practices. This potential for improvement is timely with the increasing efforts being required by more stringent regulations.

On 3 August 1993, President Clinton signed Executive Order (EO) 12856 requiring all federal agencies to comply with the Emergency Planning and Community Right-to-Know Act (EPCRA) and the Pollution Prevention Act. The EO, paragraph 3-303 directs the elimination or reduction of "unnecessary acquisition...of products containing extremely hazardous substances or toxic chemicals." The muscle behind that requirement is the EPCRA reporting requirement for Federal facilities to submit yearly

US EPA Toxic Release Inventory (TRI) Reports starting in 1995 (AFCEE, 1994:Ch4,1). The EO also mandates federal agencies, like the DOD, to set goals to achieve a 50% reduction in total releases and transfers of TRI chemicals, agency-wide. Also, the establishment of voluntary reduction goals for use and purchase of toxic chemicals is directed (AFCEE, 1994:Ch4,2). The Air Force Table of Goals is presented at Figure 3 (AFCEE, 1994:Ch1,1-2). To promulgate this policy to Air Force units, Air Force Instruction 32-7080 was published in May 1994. It directs bases to "select, use, and manage hazardous substances over their life cycle" and "develop procedures to centrally control the purchase and use of hazardous materials" (DAF, 1994:2.4) This directly suggests implementation of a HMP or similar inventory controls to help attain the goals.

The Hill AFB pharmacy was fully operational by 1993 and visited by General Yates, commander of Air Force Material Command (AFMC). The pharmacy was so well received that General Yates implemented the concept across the command by the summer of 1993 (Nelson, 1996; Moody, 1996). As an example of potential savings, one AFMC Logistics Center is reported to have dropped the cost of hazardous material procurement from $14 million to $4 million within two years by establishing a single control and authorization point (HQ USAF/LG, 1995:9).

The Air Force followed suit, publishing a Hazardous Material Pharmacy Implementation Plan on 31 May 1995. It should be noted that because the plan was specific about dictating particular operations, many bases felt it was too restrictive. To keep flexibility in the program, the plan is not being strictly enforced and an Air Force Instruction is currently in development (Mills, 1996). However, the plan's descriptive

AIR FORCE POLLUTION PREVENTION GOALS

PROGRAM COMPONENT:	GOAL:
Ozone Depleting Chemicals (ODCs):	100% Reduction of purchases by 1 Apr 93
Environmental Protection Agency 17 Industrial Toxics (EPA 17):	50% Reduction of purchases by 31 Dec 96
Hazardous Waste Minimization:	25% reduction by 31 Dec 96 50% reduction by 31 Dec 99
Municipal Solid Waste:	10% reduction by 31 Dec 93 30% reduction by 31 Dec 96 50% reduction by 31 Dec 97
Affirmative Procurement:	100% of all products purchased each year in each of EPA's "Guideline Item" categories shall contain recycled materials meeting EPA's Guideline Criteria
Energy Conservation:	10% reduction by 1995 20% reduction by 2000 25% reduction by 2005

Figure 3: Air Force Pollution Prevention Goals (AFCEE, 1994:Ch1,2)

portions are still valid. The plan states the fundamental purpose of the HMP is to minimize, track, and control the ordering, storing, distributing, using, and disposing of hazardous materials through effective use of single point control. Also, the HMP will streamline and consolidate existing tasks and provide data critical to the new reporting tasks directed by Executive Order 12856 for federal facilities to adhere to EPCRA reporting requirements (HQ USAF/LG, 1995:5).

One of the tasks of the HMP is to approve all purchase requests for hazardous materials and ozone depleting substances (ODS). In this task, the HMP validates the requirement for the material with the requester, ensures all regulatory and training approvals have been obtained, verifies the smallest unit of issue requested, and works with the requester to determine the acceptability of less hazardous or non ODS substitutes (HQ USAF/LG, 1995:10-11). The purchasing approvals are performed by HMP staff to the best of their knowledge. The tasks of validating the requirement, training, and unit of issue during the material approval process are ones that are reasonably accomplished in a timely manner. However, the determination of substitute materials is often overlooked due to lack of time, current information, training, or tools to accomplish the task. Most bases are unable to commit the time and resources to try to find substitutes for each hazardous material purchase alone, without ever attempting a material comparison based on life cycle costs or other material risk information (Moody, 1996).

The Substitution Decision

The decision to substitute one material for another is very involved and requires a large quantity of information to evaluate the trade-offs. In order to define the broad scope and difficult elements involved in the decision, a substitution framework that was presented in P2 literature is briefly described. The availability of information required in the framework is discussed and compared to Air Force information sources.

The Massachusetts Toxics Use Reduction Institute funded a study written in January 1993 by Karen Shapiro to focus on chemical substitution and develop a generic decision framework. The article, "To Switch or Not To Switch" summarizes the study and presents a decision framework for chemical substitution analysis. The framework that was presented in the article is a concise visual representation of the substitute decision to be made and is displayed in Figure 4.

The triggering mechanisms listed are factors that may trigger a substitution analysis. The list of factors appear to be comprehensive, however, there is some overlap between the effect of regulations and consumers on economics. In the case of the HMP, the task to find substitutes is directed in Air Force policy which was written considering both regulations as well as economic considerations.

The baseline characterization is an essential process, however the information may not always be known. The use and function of the material are typically known and are included as part of the HMP material request. Material hazards that are on the Material Safety Data Sheet, provided by the material manufacturer, are tracked by the HMP. But some usage hazards and especially off-site disposal hazards are probably unknown. Identification of substitutes is critical to be able to perform a comparison with the current material used in the operation. Both chemical and nonchemical, such as mechanical, substitutes should be considered. The framework provides a list of information sources, however the availability of this information to HMP staff is questionable. General P2 assistance, not specifically substitution, given in the P2 Program

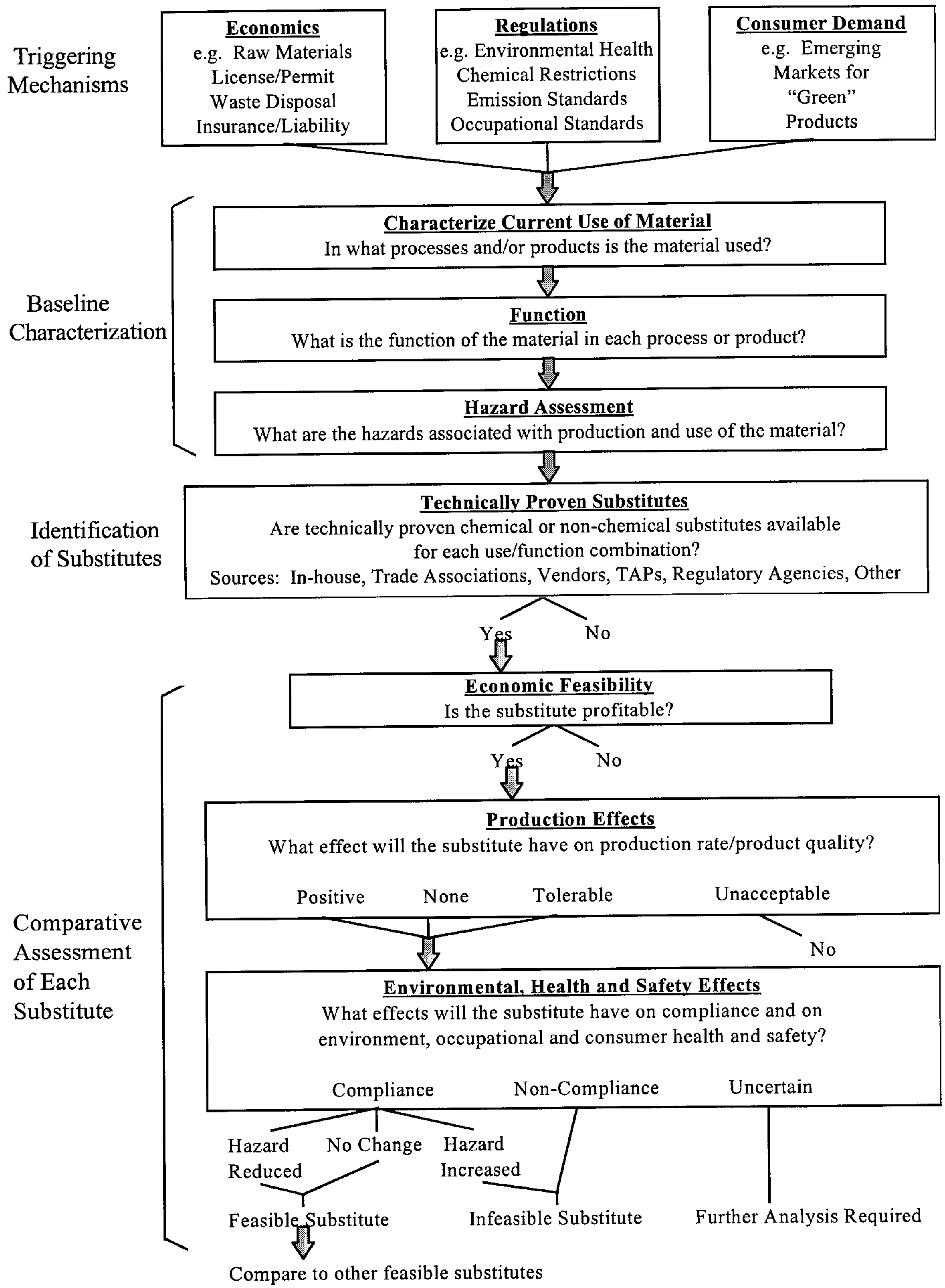

Figure 4: Substitution Decision Framework (adapted from Shapiro, 1994:4)

Guide includes a similar list of source reduction resources and a table of typical processes/opportunities for waste reduction (AFCEE, 1994:Ch3,13-18). Unfortunately, the way that many of the information clearinghouses are organized makes finding specific substitute information difficult, typically takes quite a bit of time, and still does not ensure an exhaustive search (Foecke & Style, 1992:226).

The comparative assessment process accurately addresses different levels of comparison such as economics, production and environmental effects. However, the order of considerations in the flowchart may not be appropriate and may exclude viable options too early in the process. For example, a major environmental effect may drive more serious economic consideration and acceptability of another, less profitable option. Also, there is some uncertainty about what is considered economically feasible and how it is calculated since the framework does not specify what costing procedure should be used. The Air Force HMP policy states that purchasing procedures for hazardous materials should take LCC into account without further stating how that should be done (HQ USAF/LG, 1995:11). Also, a substitute's profitability can not be fully determined without production and environmental effects information. This material comparison seems to be more cyclic or simultaneous than linear as presented in the framework.

So, the framework provides a concise visual way to show the overall concerns involved in making substitution decisions. However, a substitute option being considered should not be thrown out until all comparison information has been gathered.

No Air Force guidance attempts, like the framework, to clearly explain how to perform the material substitution requirement. Also, no Air Force training classes address material substitution or life cycle costing directly. Only the training provided for P2 Opportunity Assessments is related to material substitution by performing an analysis of current operations to find alternatives for waste generating activities. The HMP policy also does not spell out the level of effort that is expected from HMP staffs to perform the substitution decision. It seems that the omission of effort level and specific procedure may be deliberate to allow the most flexibility as possible for bases to perform substitution as they see fit. However, due to the absence of specific instruction and general lack of decision information, the requirement to perform substitution for each material purchase request seems unrealistic. If a tool exists that provides timely comparison information including the life cycle cost of the hazardous material, then its use in HMPs could foster substitution decisions to occur at a more frequent rate at Air Force installations.

Decision Analysis

The selection of a substitute material has several levels of evaluation, so selecting a tool that assists the substitute decision will also reflect the same complexity. Literature on decision analysis (DA) provides guidance for making hard decisions when faced with various uncertainties. The DA methodology is presented here because it is used to structure this complex problem. The DA steps are described in Figure 5.

DA Step #1: Determine the problem.
DA Step #2: Identify the objectives and decision criteria.
DA Step #3: Model the problem.
DA Step #4: Choose the alternative.

Figure 5: Decision Analysis Steps (Clemen, 1991:5-7)

The problem, or decision to be made, is to choose a tool that assists a HMP in its hazardous material substitution task. The difficulties involved in substitution decisions are discussed in the previous section. For the next step, the objectives and decision criteria need to be identified. If multiple objectives exist, it is possible that progress in one direction may impede progress in others. For example, if minimizing both cost and toxic risk is desired, choosing a material that costs less may have an increased toxic risk to handlers than another hazardous material. Step three, modeling the problem, will decompose the problem to understand its structure. Portraying the problem in smaller, manageable pieces is the approach. A representation, or model, of the decision problem can be described with an influence diagram. The influence diagram shows how different criteria are broken down and interact. The model is a scoring method where the importance of the criteria are weighted by the decision maker to get to step four, choose the alternative. Each tool will need to be evaluated against the decision criteria and the information input into the model. A HMP chief looking at the evaluation results can decide if a particular tool stands out, or dominates the others. But if the best tool is not obvious, the model factors in the HMP chief's criteria weights and the result suggests an alternative that best meets the needs of the decision maker.

Conclusion

This chapter has described the current literature concerning life cycle cost, the Pollution Prevention program, and the Hazardous Material Pharmacy concept. Described was the functional requirement of the HMP to select less hazardous substitutes for hazardous materials currently being purchased. The requirement can not be realistically accomplished with the current tool awareness, data availability, staff training and HMP time constraints so this task often goes unperformed. Costing tools that compare material alternatives by considering life cycle costs and other material characteristics would be instrumental to assist in the substitute decision. The complexity of the substitute decision was explored and the methodology of decision analysis described as it was used to structure this problem. Step one, determining the problem, has been described in this chapter. The bulk of the DA methodology are steps two and three, identifying objectives/criteria and modeling the problem, which will be covered in the next chapter, Research Method. Finally, choosing the alternative, will be discussed in Chapter Four, Evaluation and Analysis.

III. Research Method

Chapter Overview

This chapter describes the method this research effort uses for evaluating hazardous materials life cycle cost tools for substitution decisions in Air Force Hazardous Material Pharmacies. The methodology of decision analysis is followed to structure this complex problem. The four steps that make up the decision analysis process were shown in Figure 5 in the last chapter. Identification of objectives and decision criteria is performed in this chapter as well as modeling the problem. The research questions in Figure 6 compliment the DA steps and focus on the specific answers sought in this research. This chapter answers the first research question, by describing criteria selection important to the AF and HMP goals. The criteria, or qualities desired in costing tools, are described from existing literature, interviews and personal experience. If adequate tools exist that are strong in the decision criteria by allowing comparison of material alternatives, they would be instrumental to assist in a timely substitution decision. Next, the tools available for material substitution decisions are discussed in response to Research Question Two. The existing tools found in literature and from interviews are presented and the tools are identified that will be evaluated in Chapter Four. Finally, the decision criteria and tools to be evaluated are incorporated into a model that represents the decision. The decision is to choose a tool, once evaluated against the criteria, that best meets the values of the HMP decision maker and goals of the Air Force.

1. What criteria should be used in selecting tools to be considered able to contribute to the pharmacy requirement?

2. What tools are available to meet the functional requirement of hazardous material substitution using life cycle costing?

3. How do the tools found measure up to the selection criteria, and what improvements, if any, are suggested?

Figure 6: Research Questions

Criteria Selection

The criteria that are developed for this research effort must answer Research Question One, and be able to differentiate tool characteristics as they pertain to HMP substitution decisions. The tools will be evaluated against these criteria in the next chapter. As the DA step indicates, objectives as well as decision criteria must be identified. For purposes of this problem, the objectives are considered to be the primary Air Force goals of the HMP substitution decision. The criteria are considered to reflect the HMP staff viewpoint of tool requirements that will contribute to meeting the Air Force objectives.

First, the objectives considered to be primary Air Force goals of the HMP task of material substitution are defined. There are two primary objectives that can be derived from the HMP policy that could at times appear to be opposing each other. The first objective is to minimize the material cost by taking LCC into account during purchases. The second objective is to select materials that minimize the impact on worker safety, health and the environment (HQ USAF/LG, 1995:11). At first glance, safer materials often appear to be more expensive than their hazardous alternatives. However, in some cases, calculating the LCC that accounts for decreased handling and safety precautions of the safe material during use as well as disposal, often offsets a high purchase price making the safe material also less expensive than the hazardous alternative over its lifetime.

The decision criteria are considered to be the HMP staff's viewpoint of tool requirements that contribute to meeting the Air Force objectives. Different sources were explored to consider potential evaluation criteria including the opinions of base level Pollution Prevention Chiefs, criteria previously used for evaluations in the literature, and a detailed interview with a HMP chief. Each criterion was considered for its merits an those applicable to the HMP tool decision were consolidated into a list of criteria.

A 1995 thesis by Charlotte Hudson established environmental pollution prevention criteria by sending a questionnaire out to base-level P2 chiefs. The purpose of the questionnaire was to determine the objectives of the decision makers when selecting P2 projects for their installation. Projects for P2 must prevent pollution with the preferred method being source reduction (USEPA 1992:4-6). Since hazardous material substitution is one method of source reduction, thus a potential P2 project, the resulting values from the survey are applicable to this HMP application.

Twenty base-level pollution prevention managers completed the questionnaire. The questions and a summary of responses can be found in Appendix A (Hudson, 1995). The voiced concerns, in order of descending frequency, include: reduction of environmental impact; meeting laws and Air Force goals; obtaining money and justifying costs; hazards to human health; ability and desire to change process; operational performance; manpower; lifetime of improvement; and liability. Several of these concerns are related and can be grouped into the three major areas of hazard impact, cost, and change of operations issues. Note that cost and hazard impact minimization are exactly the Air Force objectives and operational changes include the HMP viewpoint of manpower and task time issues that are indirectly related to cost. Combining these results shows that the majority of decision makers have three main criteria when selecting projects:

1) minimizing operation's impact on human health and the environment;

2) obtaining funding with validated cost estimates in order to meet laws and goals;

3) ease of implementing the change into the process.

Decision makers most often struggle with balancing between these criteria. To single out HMP criteria, the concerns were separated into individual topics as they apply to meeting AF objectives:

- minimize human health impact
- minimize environmental impact
- minimize total costs (purchase thru cost of impacts)
- meet laws and goals (sets limits on allowable impacts)
- ease of implementation

A couple cost tool evaluations, one performed in academia and one by contract, demonstrate the diversity of criteria that can be used in an evaluation. Both evaluations were performed for application to major weapon system development. A thesis written by Mark Twomey in 1991 reviewed LCC models from a primarily financial standpoint. The characteristics he evaluated included:

1) LCC phases covered
2) budget estimates
3) warranty consideration

4) inflation and discounting,
5) risk and sensitivity analysis
6) data intensity.
7) user friendliness
8) availability (Twomey, 1991:214).

For HMP criteria, items two through five will be included in the overall life cycle cost criterion. User friendliness is a duplicate of Hudson's ease of implementation and availability is considered a requirement of all the tools to be evaluated, so is not required for comparison since each will be available.

A contract evaluation with CAPSTONE Corporation, in 1995, for the Office of the Secretary of Defense looked for environmental management cost estimating capabilities for acquisition programs using a cost breakdown structure (CBS) and cost driver categories (CDC). The CBS activities of environmental program management, hazardous material management, hazardous waste management, environmental restoration, and hazardous material and waste transportation are similar enough to the criterion of LCC phases to be considered already included. The factors that primarily affect cost, or CDCs, are hazardous substances, hazardous waste sources, personnel protection levels, and environmental management cost risk(CAPSTONE, 1995:18-22).. These cost concerns will also be included in the criterion definitions when considering the life cycle cost calculation.

Since a goal of this thesis is to find a costing tool to assist HMPs in the task of selecting less hazardous material substitutes, the viewpoint of HMP chiefs struggling with the substitution tool decision should be able to describe decision criteria to verify and supplement the criteria already identified. From personal experience of starting a

HMP as well as interviews with John Moody, the AFMC Pharmacy point of contact, and Delores Nelson, the HMP chief at Hill AFB, desired qualities in a material substitution tool were known to include criteria such as ease of use and ability to run the tool on existing equipment, in addition to the accuracy of the costing tool. To get another, separate, HMP chief's viewpoint of important decision criteria, a thorough decision analysis investigation was conducted with the Wright-Patterson AFB HMP Chief. The results of the survey are not to be considered an exhaustive survey of HMP chiefs. However, the criteria results corresponded so closely with those already identified that they were assumed to be general enough to collectively reflect the major values of most HMP chiefs.

The Wright-Patterson AFB Pharmacy Chief, Captain Rebecca Robinson, participated in a thorough decision analysis investigation of what she felt were the major drivers of selecting a substitution costing tool. The focus was any values or attributes related to deciding on a tool to use for material substitution assessment. After listing every concern she had based on discussion of HMP operation procedures and AF goals, the major items were separated from smaller sub-items, forming the value tree at Figure 7. The major items are labeled as tool values and the sub-items that are more measurable are called the attributes which are the decision criteria. Note that Robinson's first three tool values are similar to the three major objectives from the Pollution Prevention Chief survey. The final value of the tool cost made up of the cost of the tool itself and cost for any additional required equipment factors into the decision of which tool is affordable and within the pharmacy's budget.

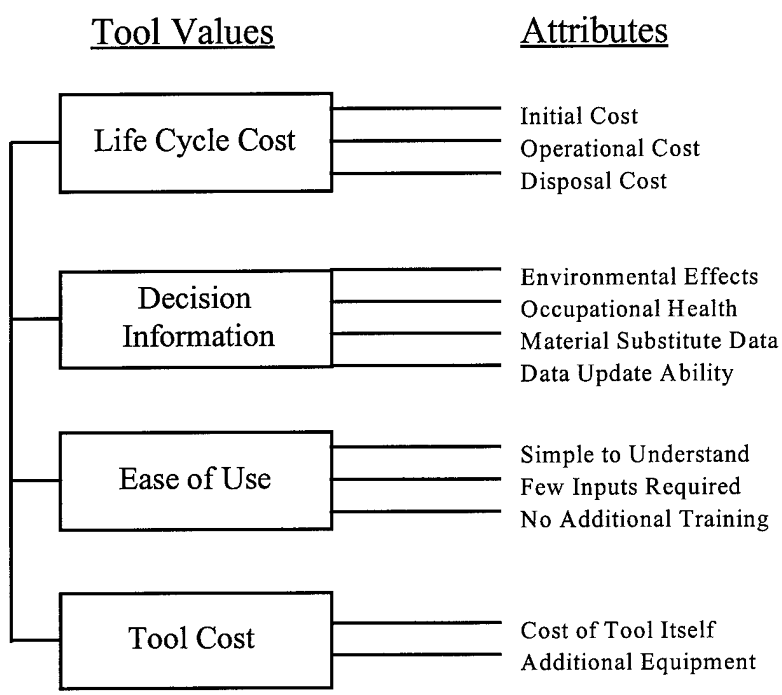

Figure 7: Value Tree

Looking at the AF objectives again, minimizing cost and reducing impacts on human health and the environment are centered on the first two tool values. A material substitute must be known or identified to even perform a cost comparison and the ability to update data will reflect the validity of the actual cost calculation. These first seven criteria can be looked at as essential to achieve the AF objectives. The last five criteria contribute to the objectives indirectly as they relate to tying up resources of manpower and budget. However, these last two tool values are considerations of the local HMP, and not necessarily a hard and fast requirement as far as meeting the intent of AF policy. Because the criteria identified by Robinson are directly related to this thesis research, those criteria will be used to evaluate the tool decision.

Criterion Descriptions

Life Cycle Cost. Because materials incur different costs throughout their lifetimes, comparison between materials using total life cycle costs is an equitable basis to ensure the total cost impact to the organization is considered. Minimizing the costs incurred or potentially incurred by the organization is the primary incentive, assuming the benefits such as reduced risk or less waste are the same.

1. Initial Cost: This is the purchase price of the material, typically on a per unit cost basis. The unit of measure used here should be the one considered throughout the life cycle cost estimate. The cost to purchase the material is assumed to take into account the initial resources used and any processing prior to the purchase. This is the point the organization becomes responsible for the material. Performance characteristics of the materials being compared must be considered by the measurement unit. This is so because a material that is less effective, say paint stripping a square yard surface, may require a larger quantity to be purchased to perform the same task.

2. Operational Cost: This may involve several component costs. First is the equipment required to use or handle the material in the process. This includes, for example, any control equipment and spill prevention kits. Second is the worker's personal safety equipment, medical examinations, and training required by occupational safety and health. Third is an additional man-hour consideration for each of the above operational requirements and another material performance comparison if more time is required per task. This may occur if a material that is less effective at paint stripping a square yard surface, requires more effort, or man-hours to perform the same task.

Finally, storage requirements may incur costs depending on the material's hazard characteristics, bulk, and volume.

3. Disposal Cost: This depends on the method of disposal chosen or required. Different hazards require different tracking and control. The method of disposal also affects whether there may be possible liability issues for the organization in the future.

Decision Information. Cost is typically a major decision consideration, but having information on other material characteristics can drive a different decision to be made in spite of the life cycle cost found. The costs alone, resulting from any environmental impacts, have already been considered in the life cycle cost category above. The actual environmental impact intangibles such as management effort from regulatory requirements and future risk are considered separately here as decision information for comparison. Maximizing the pertinent information available to the decision maker is desirable.

4. Environmental Effects: Both the material's impact on the environment and existing regulatory requirements affect the organization's bottom line but are usually difficult to quantify as a direct cost. Any environmental effects analysis or documentation could indicate a difference between the materials in possible public relations work and future liability exposure. The regulatory requirements may require controls already accounted for in the operational or disposal cost, but listing them may indicate a difference in management or reporting efforts.

5. Occupational Health: Like the environmental effect, both the material's impact on the worker safety and existing regulatory requirements affect the organization's

bottom line but are usually difficult to quantify as a direct cost. The difference between the materials may be in worker confidence, future health liability, and regulatory management or reporting efforts.

6. Material Substitutes: Having alternate materials suggested by the model, an associated database, regulatory agency, crossfeed information tried in industry by process, material suppliers, or in-house is essential for this comparison analysis. Credibility of the source of information is a concern along with the completeness of the included information on various technological areas.

7. Data Update Capability: The data used to calculate the life cycle costs, as well as the other decision information of environmental, occupational and substitute information must be able to be updated during a reasonable timeframe. This is essential to keep the resulting information credible for use in decision making and would control the cost risks associated with cost increases or technology developments.

<u>Ease of Use</u>. Even if a cost tool meets the above criteria, the effort that must be expended by the pharmacy staff to understand and use the tool appropriately should be minimized. A tool that is easier to integrate into the workplace may take precedence over a tool that is totally rigorous in the above seven criteria.

8. Simple: The construction and theory behind the tool needs to be simple to understand or have descriptive elements to ensure proper usage of the tool.

9. Few Inputs: The data inputs to the tool should be minimal or able to be selected from baseline default values prompted by the tool. If inputs must be collected

from the process, the tool should explain methods to collect them and any implications. The inputs or defaults should minimize the time to use the tool while keeping validity.

10. No Additional Training: Minimizing the training required to use the tool is desirable. This includes tool operation, as well as any additional equipment or software required by the tool.

Tool Cost. The costs associated with acquiring the tool and any equipment or software to operate it should be minimized.

11. Availability/Cost of Model: The tool or model should be available for public or government use and its price is a consideration for budgeting purposes.

12. Additional Equipment: Just as additional equipment may require training, any equipment or software costs required by the tool are to be considered.

It is important to note that there are two decision levels that arise in this framework: 1) items that affect the selection of a substitute hazardous material, and 2) items that affect choosing the tool. In the value tree presented in Figure 7, the first seven attributes considered are relevant to what the tool uses as the basis for selection of substitute materials. The way the life cycle cost is calculated and what other decision information is considered are both part of the tool's methodology for material selection. This tool methodology establishes the procedure the tool uses to select alternate materials. Whether it is quality calculation of LCC or other decision considerations such as environmental risk, or data quality. The more agreement with the methodology, the more confidence the decision maker can place in the tool's results.

Once a tool's material selection criteria are found to be acceptable, the last five attributes provide added information important for the user's choice between acceptable tools. The ease of use and cost of the tool itself are important drivers in the practical decision of which tool is best to try in an application. Although these criteria are not as critical and may be overlooked in evaluations concerned only with tool methodology, they form rationale of whether the tool will be used and whether it makes business sense to try the tool in the first place. Once these criteria are evaluated, a complete decision framework exists to allow an informed decision to be made between cost tools on a credible, applicable, and practical basis.

Life Cycle Substitution Tools

The tools identified in this research effort answer Research Question Two, as long as they are available to pharmacies and are able to meet a need of the material substitution decision. Different types of tools provide different information to the decision as they pertain to HMP substitution. The tools along with the decision criteria form a decision model presented in the next section. Actual evaluation of the tools against the criteria is performed in the next chapter.

Types of Tools. New model development and improvement to existing cost tools has been a lengthy process driven by government and industry requirements. Early LCC models used by the Air Force in the 1970s were found to have several deficiencies and typically concentrated on only a specific portion of a weapon system's life cycle. A 1975 review of available LCC models by the Joint AFSC/AFLC Commanders' Working

Group on LCC acknowledged that although the models could provide valuable guidance, models were found to:

- be insensitive to weapon system performance and design parameters,
- be too complex,
- require data input that frequently could not be provided in a timely manner or with a reasonable level of confidence, and
- be insensitive to wear-induced failures. (Twomey, 1991:17-18)

Another appraisal, conducted by RAND Corporation in 1978, reviewed eight system models and found that the models were insensitive to important cost drivers and inconsistent with definitions of cost elements (Twomey, 1991:18).

Despite this early criticism, LCC models continued to be developed and used on an increasing basis. Advances in microcomputer technology during the 1980s improved the accessibility of LCC models and encouraged the proliferation of models as individuals modified generic models to suit their particular circumstances (Twomey, 1991:21). LCC models were being developed for specific applications and LCC regulations and methodologies continued to be refined and institutionalized as smart business practices.

With this boom in model development, there came a need to classify the different types of LCC models and their uses. Several different classification schemes have been used. Three types of LCC models were described by Twomey:

1. Cost factor models
These models, based on Air Force-derived cost factors, are used to compute weapon system operations cost estimates. The estimate is the sum of cost elements achieved by multiplying the cost factors by parameters like flying hours, number of weapons purchased, or flyaway cost of the new system. The model is easy to use, but reflects only the major system cost elements and not the subsystem cost elements.

2. Accounting models

Used to a greater extent, this type of model allows operations costs to be computed at the lowest system element level then sums them for the system. Parametric cost models are accounting type models. They use easily quantified variables like size and weight to estimate more complex variables such as total system LCC. The key feature of the parametric model is its ability to be calibrated to specific values obtained through the study of similar situations in the past. The disadvantages of accounting models relate to the detailed breakdown of information they need to operate. The requirement for a large amount of data brings with it the potential problem of standardization. Additionally, validation of the large amount of input data becomes a concern.

3. Optimizing models
These models maximize across a subset of support alternatives in order to minimize operations costs. The model is easy to use, like the cost factor type models. The main limitations of this type of model are the requirement for an allocation procedure and the lack of capability to cost out low level repairs.
(Twomey, 1991:25-28)

The model types have expanded and changed since 1991. A recent evaluation of environmental cost-estimating capabilities for acquisition program use was performed by the CAPSTONE Corporation and published in March 1995. Their search identified several different types of cost-estimating tools, including written case studies. Each of the tools was placed in a classification to determine its usefulness:

- Classification 1: Unit-Cost Models and Databases
- Classification 2: Parametric Cost Models
- Classification 3: Project Cost Databases
- Classification 4: Engineering Case Studies and Reports
- Classification 5: Project Management Systems
- Classification 6: Application Software Programs (CAPSTONE, 1995:13)

Classification 5, project management, was eliminated from further consideration by CAPSTONE because such tools offered little or no content specific to environmental cost estimating. CAPSTONE eliminated Classification 6, application programs, from consideration because such tools provided only templates, not unit-cost data or cost-estimating relationships. These tool classifications will be used to categorize the models that are found in the next section.

Existing Tools. To find models in the academic literature, a search was performed on Proquest and EI Monthly databases for LCC, life cycle models, hazardous materials and material substitution tools. Very few models were applicable to the hazardous material substitution decision. By talking to people knowledgeable about life cycle costing, a couple studies were identified that have evaluated life cycle models used in weapon system acquisition. While the acquisition models may be helpful to consider, no study to date has focused specifically on hazardous material pharmacy requirements.

Since the studies performed on 1970s LCC models found the models to have several deficiencies and typically only a partial life cycle view, those models will not be considered in this evaluation. A thesis by Mark Twomey in 1991 reviewed selected USAF LCC models, including:

O&S Models	- Logistic Support Cost (LSC)* - Life Cycle Cost H (LCCH) - Cost Oriented Resource Estimating (ZCORE)
Multi-Phase Models	- Cost Analysis and Strategy Assessment (CASA) - Parametric Review of Information for Costing & Evaluation (PRICE) family - Modular Life Cycle Cost (MLCC)
Specialized Models	- Dynamic Multi-Echelon Technique for Recoverable Item Control (Dyna-METRIC)* - Logistics Composite (LCOM)*

*Only these models have been formally validated.

None of the above models take into account the disposal phase of the life cycle, critically important for hazardous materials, so they will not be included in this evaluation (Twomey, 1991:213-214).

The 1995 study by CAPSTONE Corporation, under contract to the Office of the Secretary of Defense, evaluated several cost-estimating models, databases and case studies. Screening out the ones that were not available, CAPSTONE evaluated the following models and databases:

- Hazardous Material Life Cycle Cost Estimator (HAZMAT)
- Historical Cost Analysis System (HCAS)
- Remedial Action Cost Engineering and Requirements (RACER)
- Micro-Computer Aided Cost Engineering Support System (MCACES)

(CAPSTONE, 1995)

The first three models will be evaluated in Chapter Four. The MCACES model is not evaluated in this thesis due to its similarity in structure and estimation ability to the HCAS model, hence no capability is lost by overlooking it.

Stepping away from the sole application of acquisition, a thesis by Burley and Phillips in 1993 evaluated LCC models to select cost-effective alternatives for hazardous materials including:

- AF Hazardous Material Life Cycle Cost Estimator
- EPA Life Cycle Design Model
- Rankin & Mendelsohn Pollution Prevention Model
- DOE Waste Analysis Model

The estimator is applicable for evaluation in this thesis, but it will be ignored since it is the old version of the HAZMAT model which is already being considered. In addition, Burley and Phillips develop their own cost model for making these material selections (Burley and Phillips, 1993). Their model will be evaluated in Chapter Four.

At least two informational databases are available that were discovered in P2 literature. One is the EPA Pollution Prevention Information Clearinghouse, established by the EPA in compliance with the directive to do so in the Pollution Prevention Act (HR5931, 1990:5-8). The other is a help line for Air Force use only, called PRO-ACT, established under a contract with Brooks AFB Air Force Center for Environmental Excellence (AFCEE, 1994:Ch3,13). Both of these databases will be evaluated.

By conducting interviews with people in HMP positions, a project management system called Hazardous Material Procurement Action Tracking System (HazMat PATS) was identified. The system was developed in the field to assist in prioritizing material purchases based on lessening its hazardous content (Robinson, 1996; Nelson, 1996). This system will be evaluated in Chapter Four.

Model of the Cost Tool Decision

The values and attributes important to the HMP Chief are used as the building blocks for the model, since they are assumed to be representative criteria of the HMP decision makers and were found to be applicable for assisting in the material substitution cost tool evaluation. The decision representation, or model, portrays the problem in small manageable pieces with possible interactions between different criteria. The structure of the cost tool decision is more easily depicted by the use of Decision Processing Language (DPL) which can show an influence diagram of the criteria influences on the overall decision.

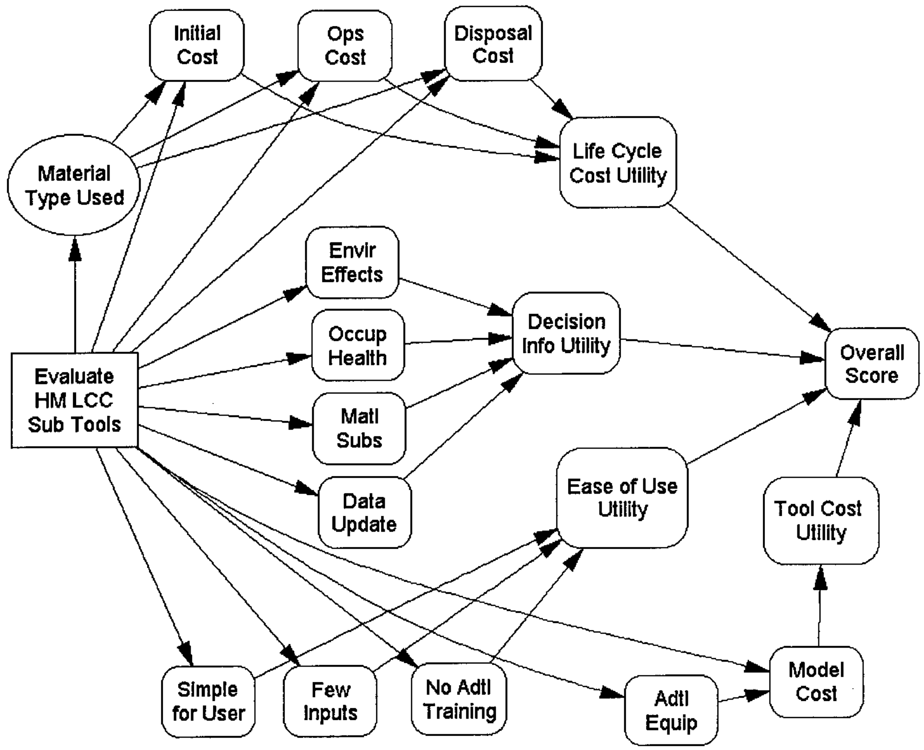

Figure 8: Decision Influence Diagram

In the influence diagram, Figure 8, the choice or decision to be made within the square shape is between the different costing tools being evaluated. The uncertainty of what material type will need substitution evaluation is represented by the oval. Three major material types, namely laboratory chemicals, paints/stains/adhesives, and solvents, were used in this model because they were the largest quantity used by Robinson at Wright-Patterson AFB, hence the most likely to be evaluated for substitution. Note that the four utility functions that factor into the overall score are the four major values identified by the decision maker. A more complete description of how the model functions in DPL is at Appendix B.

Although not the purpose of this research, the evaluation results from Chapter Four can be entered into each criteria, or attribute node represented by a round-cornered rectangle. The utilities described for each of the four major values are defined with variables for the decision maker's weighting and the tool's evaluation of the criteria. Entering the evaluation results and the decision makers weights, the model could calculate a resulting score for each tool from zero to one for the current decision maker. Proof of the utility equations and analysis of the model's scoring ability is beyond the scope of this research effort.

Understanding the effect of a decision maker's weighting of criteria, however, should be understood. For example, different people may value different attributes more than others depending on the application in which the tool will be used. If money is the primary driver in the material substitution search, then LCC would be more heavily considered than occupational issues arising from the material decision. The evaluation of tools, answering Research Question Three, is performed in the next chapter with a qualitative description and summary table so pharmacy chiefs can weigh the importance of the criteria against their situations. If one HMP chief weighs the criteria much differently than Robinson, then that chief could actually prefer a different tool than the one Robinson's model would recommend. The bottom line is, if the tool being evaluated does not consider the main issues important to the decision maker, then the tool will not produce acceptable results in their eyes and should not be considered any further.

IV. Evaluation and Analysis

Chapter Overview

This chapter presents the evaluation of tools previously identified and measured against the selected decision criteria. The criteria were developed into a representation, or model, to understand the choice of existing cost tools for material substitution decisions in a Hazardous Materials Pharmacy (HMP). So far, Research Questions One and Two shown in Figure 9, selecting criteria for substitution tools and identifying available tools, were both answered in the last chapter titled Research Method. The model is used as a framework of ideal considerations for the actual tools to be compared with. In this chapter is presentation of an evaluation table to rate the tools against criteria, tool classifications, and evaluations of available cost tools to answer Research Question Three.

1. What criteria should be used in selecting tools to be considered able to contribute to the pharmacy requirement?
2. What tools are available to meet the functional requirement of hazardous material substitution using life cycle costing?
3. How do the tools found measure up to the selection criteria, and what improvements, if any, are suggested?

Figure 9: Research Questions

Evaluation Table

To assist in comparison of the cost tool evaluation results, a table form of the decision criteria is presented in Figure 10. This table has the same categories of evaluation that are relevant in the decision framework influence diagram presented in Chapter Three, but simplifies the visual representation of them. Each criterion, or attribute, is evaluated on a scale with three divisions, where the measurement represents the quality of coverage for each criterion. The model either meets the criterion (yes), does so to a limited extent (limited), or does not meet the criterion at all (no). The detailed criterion descriptions are in Chapter Three. A summary description of the major values follows.

Major Value	Attribute	Rating:	Yes	Limited	No
Life Cycle Cost	Initial Cost				
	Operational Cost				
	Disposal Cost				
Decision Information	Environmental Effects				
	Occupational Health				
	Material Substitutes				
	Data Update Capability				
Ease of Use	Simple				
	Few Inputs				
	No Additional Training				
Tool Cost	Availability/Cost of Model				
	Additional Equipment				

Figure 10: Evaluation Table

Major Value Descriptions

Each of the four major decision values describe a different aspect of the costing tool decision. Each pharmacy decision maker has different weights associated with each criterion. For this reason, the results will be presented in tabular format instead of a calculation of a score for each tool. However, remember that the top seven attributes are required to meet AF goals while the last five are just for consideration by HMP chiefs.

Life Cycle Cost. Because materials incur different costs throughout their lifetimes, comparison between materials using total life cycle costs is an equitable basis to ensure the total cost impact to the organization is considered. Minimizing the costs incurred or potentially incurred by the organization is the primary incentive. The attributes, or sub-categories are: 1. Initial Cost, 2. Operational Cost, and 3. Disposal Cost.

Decision Information. Cost is typically a strong decision consideration, but having additional information on other characteristics influence the decision in spite of the life cycle cost found. Maximizing the information available to the decision maker is the driver. To make an informed decision the following information is desired: 4. Environmental Effects, 5. Occupational Health, 6. Material Substitutes, and 7. Data Update Capability.

Ease of Use. Even if a cost tool meets the above criteria, the effort that must be expended by the pharmacy staff to understand and use the tool appropriately should be minimized. A tool that is easier to integrate into the workplace may take precedence over a tool that is totally rigorous in the above seven criteria. Ease of use attributes are: 8. Simple, 9. Few Inputs, and 10. No Additional Training.

Tool Cost. The costs associated with acquiring the tool and any equipment or software to operate it include: 11. Avail/Cost of Model, and 12. Additional Equipment.

Cost Tool Classifications

The tools found for this evaluation resulted from a literature search of life cycle costing models, past cost model studies, and interviews with people in the field of hazardous material use reduction. The search resulted in many different types of tools so those to be evaluated are placed into classifications in Figure 11. Evaluations of the tools follow in the next section.

Classification 1: Unit-Cost Models and Databases

- Hazardous Materials Life Cycle Cost Estimator (HAZMAT)

Classification 2: Parametric Cost Models

- Burley and Phillips Decision Support Model
- Remedial Action Cost Engineering and Requirements (RACER)

Classification 3: Project Cost Databases

- Historical Cost Analysis System (HCAS)

Classification 4: Engineering Case Studies and Reports

- EPA Pollution Prevention Information Clearinghouse
- AFCEE PRO-ACT

Classification 5: Project Management Systems

- Hazardous Materials Procurement Action Tracking System (HazMat PATS)

Figure 11: Tool Classifications

Cost Tool Evaluations

The cost tools classified above were selected for evaluation based on their potential to be applied to the material selection decision of a Hazardous Materials Pharmacy and their availability for evaluation. The models are assessed using the developed criteria included on the evaluation table.

Hazardous Materials Life Cycle Cost Estimator (HAZMAT). This cost tool was developed for the Air Force Human Systems Center at Brooks AFB under contract by The Analytical Sciences Corporation (TASC) of Fairborn, OH. TASC began the development effort in 1990, and it is ongoing. The latest version of HAZMAT (3.1), with supporting documentation from 1994, is used for this evaluation.

Description of Model: HAZMAT was developed to support DOD pollution prevention initiatives conducted through a weapon system's life cycle. It was designed to perform cost trade-off studies between currently used hazardous materials and other materials.

Methodology: HAZMAT calculates estimates from a database of the costs for manufacturing and maintenance process operations for eight weapon systems composed of aircraft, ground vehicles, space launch vehicles, and selected subsystems. In addition to these processes, the model considers related management costs in the area of hazardous material management, medical, liability and regulatory cost risk. To account for possible multiple systems in a facility, the material cost comparison for a weapon system is based on the ratio of pounds of the subject weapon system to the total pounds for all weapon systems at a facility. The output of the model is by acquisition phase (acquisition, operating and support, and decommissioning) and by cost element (procurement, medical, personal protection, handling, management, legal/environmental, and disposal).

Evaluation: The evaluation sheet for HAZMAT is at Figure 12. Each attribute's evaluation is discussed individually below the evaluation sheet.

Major Value	Attribute	Rating: Yes	Limited	No
Life Cycle Cost	Initial Cost	X		
	Operational Cost	X		
	Disposal Cost	X		
Decision Information	Environmental Effects			X
	Occupational Health		X	
	Material Substitutes		X	
	Data Update Capability			X
Ease of Use	Simple		X	
	Few Inputs		X	
	No Additional Training		X	
Tool Cost	Availability/Cost of Model	X		
	Additional Equipment	X		

Figure 12: Evaluation Sheet for HAZMAT

Looking at life cycle cost elements, HAZMAT considers the three components as described here. Initial material cost, called the acquisition cost phase, is entered after picking a system (ex: aircraft/ vehicle/launch), type (ex: fighter/tank), and subsystem (ex: airframe/solid rocket). The performance is factored in because the unit of effort for comparison (ex: square feet) is queried. Operations cost, or the phase of operating and support is considered, after picking a system (ex: aircraft/vehicle/launch), type (ex: fighter/tank), and subsystem (ex: airframe/propulsion unit). The number of systems and operating sites factors into the equipment requirement. The performance is still factored in because the unit of effort for comparison (ex: square feet) is queried. There is no indication of worker safety equipment or storage requirements here, but it is included in the cost sub-elements of personal protection, handling, and facilities. Finally, HAZMAT considers the cost impact of off-site treatment and disposal, or the phase of decommissioning, after picking a system (only aircraft), type (ex: fighter/bomber), and subsystem (only airframe). The surface area (ex: square feet) is the measure of disposal activity for the system and potential liability is covered in a cost sub-element.

Decision information however, is not as strong as LCC. HAZMAT considers environmental effects and occupational health effects in a limited manner as they impact cost because it is strictly a cost model. The costs of impact to the environment and regulatory requirements are covered by "potential liability" and "management," respectively. There is no effects information or applicable regulations listed. The cost of impact to worker safety is addressed by "personal protection," "training," "medical," and potentially "handling." The cost of regulatory requirements are covered by "management." There is no worker safety issue information or applicable regulations listed. For substitution, HAZMAT lists all known substances for the process of interest (ex: airframe adhesive bonding) by national stock number. Although materials with the same NSN may be interchangeable, the specific function of the material or performance required is not described except for the material name itself. A new substance's information can be input or an existing one modified for comparisons as long as the user knows it is an acceptable substitute. HAZMAT has no database updating capability. Any additional weapon system data collected is eventually added to the model if/when a new version is published. Data known by the user will be useful only if the user knows the process well enough to make the appropriate inputs on the several modification screens.

For ease of use, HAZMAT had limited marks. The screens are relatively simple to understand if the material evaluation being made is for a weapon system type that is included, or very similar to a type, in the database. The modification screens define the inputs generally. HAZMAT has few inputs only if the material evaluation being made is for a weapon system type that is included, or very similar to a type, in the database. Deviations from the default values can be difficult if process information is not well known. Time saved by using defaults may quickly erode validity of the estimate. HAZMAT does not require any difficult additional equipment to run the model, once the windows version is released. The model itself though should be used by someone trained in cost analysis or closely involved in the process to be able to collect valid data values.

Finally, concerning tool cost, HAZMAT is a model developed for the Air Force by contract, so it is available for government use at no cost. HAZMAT does not require special equipment to run except a standard microcomputer that most Air Force offices already have.

Overall: The cost elements are a thorough picture of potential costs. They include procurement, transportation, personal protection, management, training, handling, potential legal/environmental liability, medical, facilities, and support equipment. The HAZMAT model only calculates the cost by phase, not for the total weapon system environmental cost, although it could be figured by running all three phases. It could be useful in conducting pollution prevention trade-off studies for a particular acquisition phase (CAPSTONE, 1995:11). A disadvantage of the model is the detailed breakdown of information it needs to operate. The default values can be used but unless the process being evaluated is completely understood, the user can not know if the defaults are appropriate for their application. Unfortunately, this model's usefulness is limited to weapon system material substitution because the cost data within the model is derived from specific weapon systems and life cycle cost estimates are derived in terms of a specific type of weapon system and acquisition phase. This is not typical for pharmacy material substitution decisions unless finding a technical order material substitute during the operation & maintenance phase.

Burley & Phillips Decision Support Model (B&P DSM). This model was developed in a masters degree thesis in September 1993, at Air Force Institute of Technology, Wright-Patterson AFB Ohio.

Description of Model: It is a decision support model that provides formulas for performing life cycle cost analysis to compare alternatives for hazardous materials.

Methodology: Life Cycle Cost categories were selected, equations were developed, then a decision support model was developed around them. The categories include procurement, transportation, facility, training, handling, personal protection, monitoring, medical, emergency response, disposal, liability, and intangible costs. This model explains step-by-step procedures for evaluating economic feasibility of alternative materials using a net present value approach to compare the alternatives with the baseline.

Evaluation: The evaluation sheet for B&P DSM is at Figure 13. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating:	Yes	Limited	No
Life Cycle Cost	Initial Cost		X		
	Operational Cost		X		
	Disposal Cost		X		
Decision Information	Environmental Effects				X
	Occupational Health			X	
	Material Substitutes				X
	Data Update Capability				X
Ease of Use	Simple			X	
	Few Inputs				X
	No Additional Training			X	
Tool Cost	Availability/Cost of Model		X		
	Additional Equipment			X	

Figure 13: Evaluation Sheet for B&P DSM

Life Cycle Cost considerations of the model are very thorough. This is evident from the cost categories listed above in the methodology. Each life cycle attribute is covered from initial costs and operational costs to disposal costs. Note that the cost categories for this model are very similar to the categories in HAZMAT.

Decision information, on the otherhand, is not as strong as LCC. Environmental effects and occupational health are incorporated to a limited extent into the life cycle calculation based on the cost categories. However, no list of effects or requirements is generated by this model. Material substitutes are not addressed at all by this model and there is no data update capability. All data must be obtained on a case by case basis.

Ease of use is limited in the two areas of simplicity and no additional training because although the formulas are spelled out, it requires some knowledge of the formula construction to apply them to appropriate situations. Few inputs is not met at all due to having to manually input and calculate all the formulas.

Tool cost is free in that the formulas are provided. However, additional equipment may be needed in the form of a program or processor to calculate the life cycle costs.

Overall: This model has the required life cycle element because it is focused on the financial calculations. However, it is difficult to use and update data due to it being a paper based model. It really needs a computer format to perform the cost computations and a database of current cost factors that is able to be updated.

<u>Remedial Action Cost Engineering and Requirements (RACER)</u>. This model was developed by Delta Research Corporation in Niceville, Florida for the Air Force Engineering and Support Agency, Tyndall AFB FL.

Description: RACER is a strong parametric cost estimating model.

Methodology: It was developed for cost estimating projects that involve costs associated with environmental restoration and corrective measures.

Evaluation: The evaluation sheet for RACER is at Figure 14. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating:	Yes	Limited	No
Life Cycle Cost	Initial Cost				X
	Operational Cost				X
	Disposal Cost		X		
Decision Information	Environmental Effects				X
	Occupational Health			X	
	Material Substitutes				X
	Data Update Capability			X	
Ease of Use	Simple			X	
	Few Inputs		X		
	No Additional Training			X	
Tool Cost	Availability/Cost of Model		X		
	Additional Equipment			X	

Figure 14: Evaluation Sheet for RACER

RACER is not considered a complete LCC model, because it only attempts to estimate costs in a remediation or environmental corrective application. It is not concerned with the initial or operations costs that have been paid.

Decision information is limited for most criteria. Environmental and health effects as they apply strictly to remedial action are modeled but there is no listing of possible outcomes and related regulations. Data update is limited to modification of the parametric model itself since the cost relationships may vary with time.

Although there are relatively few inputs to the model, there is a need for understanding of model parameters and additional training to use RACER correctly. The training will require equipment such as manuals or software for instruction.

The RACER model software is provided from the Air Force Engineering and Support Agency. The only concern about additional equipment is the consideration of having a dedicated computer to operate at peak performance.

Overall: RACER is one of the better remedial cost estimators due to the minimal input required. However, the limited input also implies a great deal of assumption in the model. Also, RACER does not take the complete life cycle into account for LCC considerations in purchasing.

<u>Historical Cost Analysis System (HCAS)</u>. This system was developed by the Interagency Cost Estimating Group composed of the U.S. EPA, DOE, and DOD.

Description: This is a historical project cost database, creating cost estimates by comparing the similarities of a current project with a past one and adjusting for the differences in scope and time with cost factors.

Methodology: The data in this model are based on past project costs. It can directly calculate facility closure and post- closure care.

Evaluation: The evaluation sheet for HCAS is at Figure 15. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating: Yes	Limited	No
Life Cycle Cost	Initial Cost			X
	Operational Cost			X
	Disposal Cost	X		
Decision Information	Environmental Effects			X
	Occupational Health		X	
	Material Substitutes			X
	Data Update Capability		X	
Ease of Use	Simple		X	
	Few Inputs		X	
	No Additional Training		X	
Tool Cost	Availability/Cost of Model	X		
	Additional Equipment	X		

Figure 15: Evaluation Sheet for HCAS

HCAS is not a LCC model, because it only attempts to estimate costs in a remediation or environmental corrective application. It is not concerned with the initial costs or operations costs that have been paid.

Decision information is limited for most criteria. Environmental and health effects as they apply strictly to remedial action are modeled but there is no listing of possible outcomes and related regulations. Data update is limited due to infrequent collection and incorporation of additional cost data.

Although there are quite a few inputs to the model, in order to keep the estimate reflective of the actual project. Also, there is a need for understanding of model cost factors and additional training to use HCAS properly. No additional equipment is required over standard office equipment.

Overall: HCAS is one of the better project cost databases. However, it does not take the complete life cycle into account. It covers only restoration and corrective environmental measures, neglecting the critical operations costs that can drive hazardous materials pharmacy substitution decisions.

EPA Pollution Prevention Information Clearinghouse (PPIC). The requirement for this information repository was established by the 1990 Pollution Prevention Act. The U.S. EPA designated a department to track pollution prevention information which assists industry with adopting source reduction techniques.

Description: The clearinghouse fosters the exchange and dissemination of source reduction information to businesses (HR5931, 1990:298-302). This clearinghouse contains various publications, databases, and technical references. The Pollution Prevention Information Exchange System (PIES) allows users to access some PPIC information through an on-line computer system. The voice line is at (202)260-5723 and the PIES system line is (703)506-1025

Evaluation: The evaluation sheet for PPIC is at Figure 16. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating:	Yes	Limited	No
Life Cycle Cost	Initial Cost				X
	Operational Cost				X
	Disposal Cost				X
Decision Information	Environmental Effects				X
	Occupational Health			X	
	Material Substitutes			X	
	Data Update Capability			X	
Ease of Use	Simple		X		
	Few Inputs			X	
	No Additional Training		X		
Tool Cost	Availability/Cost of Model		X		
	Additional Equipment		X		

Figure 16: Evaluation Sheet for PPIC

Life cycle cost models are not available from the service, however some reports might discuss related topics. A case study or database may be found with life cycle data.

All decision information criteria are probably on the system in some form, whether report, case study, or a database. The reason it is rated as limited is the information's availability is questionable since it may be buried in documents and is not always pulled out effectively from a word search performed on the service.

Using the system is simple once the access number is known and the new user registered. It does not take special training, except possibly getting better at keyword searches. The input level is rated as limited because many searches may be performed before ever getting anything useful. Also, there are many systems that can be accessed through PPIC which add to the complexity and time spent on the system.

The time per day is limited to ninety minutes per user on PPIC. Other than the time restriction, availability is good.

Overall: PPIC is a helpful system with access to many information sources, although it may be easy for a new user to get bogged down or easily discouraged if results are not found in a timely manner. Other than that, it is easy to use.

Air Force Center for Environmental Excellence (AFCEE) PRO-ACT. An Air Force contract service provides the PRO-ACT Environmental Information Clearinghouse. It is for Air Force use only.

Description: PRO-ACT is reached by phone, at DSN 240-4214 or commercial (800)233-4356, to handle a range of environmental information inquiries. The staff are able to field questions and perform some research if the answer is not readily available. They can help with interpreting regulations to finding needed documents or sending reports. Their queries are posted each month on a bulletin board on the world-wide web if scanning recent topics by computer is desired.

Evaluation: The evaluation sheet for PRO-ACT is at Figure 17. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating: Yes	Limited	No
Life Cycle Cost	Initial Cost			X
	Operational Cost			X
	Disposal Cost			X
Decision Information	Environmental Effects			X
	Occupational Health		X	
	Material Substitutes	X		
	Data Update Capability		X	
Ease of Use	Simple	X		
	Few Inputs	X		
	No Additional Training	X		
Tool Cost	Availability/Cost of Model	X		
	Additional Equipment	X		

Figure 17: Evaluation Sheet for PRO-ACT

PRO-ACT does not have life cycle models available. Some acquisition cost model documentation is available, however it is not useful for daily operations material substitution alternatives.

Operations such as the pharmacy substitute decision are tied closely to the process itself and particular industry/material restrictions. So, specific substitution material databases are available through the service. PRO-ACT has some limited environmental and health impact information available, as well as some data from different case studies.

Ease of use criteria are all met due to the simplicity of calling and being able to discuss the particular need with a researcher who does the work and provides the search results.

Availability is good from the phone. It costs nothing for Air Force callers and requires no special equipment.

Overall: PRO-ACT is a worth while service to seek answers to environmental questions. The researchers provide the results of any search they perform. However, acquiring specific software or database access that directly connects to the information would be more effective than calling each time.

Hazardous Material Procurement Action Tracking System (HazMat PATS). This decision tool was developed by General Atomics for Hill AFB, Utah.

Description: Haz Mat PATS is a system to prioritize materials for purchase on the supply list based on reduced hazardous material content as derived from supplier information and material safety data sheets. PATS is a large system that was initially poorly received. The stock number matching with material safety data sheets component of the system is currently being developed on its own and called Procure Smart.

Methodology: The approach is to prioritizing purchases to reduce toxic chemical use. It takes National Stock Numbers (NSNs) for hazardous materials and identifies the material restrictions or regulatory issues related to its use (ex: TRI, EPA 17,or flammable) The base ranks these issues and assigns a weight factor to each. Then when a material is requested for purchase, a figure of demerit is calculated for the material which can be compared to other vendors of the same product with equitable stock numbers, looking for a lower impact.

Evaluation: The evaluation sheet for HazMat PATS is at Figure 18. Discussion of the attribute evaluations is discussed below the evaluation sheet.

Major Value	Attribute	Rating: Yes	Limited	No
Life Cycle Cost	Initial Cost			X
	Operational Cost			X
	Disposal Cost			X
Decision Information	Environmental Effects		X	
	Occupational Health	X		
	Material Substitutes	X		
	Data Update Capability		X	
Ease of Use	Simple	X		
	Few Inputs	X		
	No Additional Training		X	
Tool Cost	Availability/Cost of Model	X		
	Additional Equipment		X	

Figure 18: Evaluation Sheet for HazMat PATS

This system does not use life cycle cost, or any costs at all, for prioritization consideration. This is typical for project management systems.

However, the system is noteworthy due to taking the hazards of the material or material components into account. A good feature is the Federal Supply Catalogue Substitutability List is a part of the database to suggest approved substitutes. The data update capability is limited because although no update was possible previously, it has recently been modified to update from the supply lists monthly. It does not have an active interface to ensure constant accuracy.

This system is simple and takes the mere input of a stock number. However some training to use it is required to be able to manipulate the demerit calculation,

The system is available for use although it is undergoing beta testing and additional equipment is needed because it is a stand-alone system.

Overall: The prioritization makes reduction of hazardous materials use the goal of the system. Use of supply records is effective for simplifying ordering and showing alternatives. There is concern that it does not have a way to handle local purchase materials and the approved substitute material list was not able to be updated with the monthly NSN release.

Summary

This chapter has laid out an evaluation table and measured the characteristics of the tools against the decision criteria. This has answered Research Question Three of which tool meets the decision criteria. Considering that no one tool was strong across the board, a mixture of tools may need to be used to perform hazardous material substitutions until a tool is developed that meets more of the decision requirements.

V. Conclusions and Summary

Chapter Overview

This chapter presents a summary of the results of this research effort to evaluate hazardous material cost models for use in Air Force Hazardous Material Pharmacies. The evaluation was structured through the research questions reviewed below. The questions are followed by the answers that were found through this research effort. The results are discussed in the broad context of an everyday application to an operational hazardous materials pharmacy. Potential areas for future research and development are presented, followed by a brief wrap-up of the thesis effort.

Research Design

This research problem was structured by formulating questions fundamental to material substitution issues of an Air Force Hazardous Materials Pharmacy. The research questions in Figure 19 are the design elements of this effort, the answers to which shed light on what tools are available or are needed to reduce hazardous materials use on base through material substitution efforts.

1. What criteria should be used in selecting tools to be considered able to contribute to the pharmacy requirement?
2. What tools are available to meet the functional requirement of hazardous material substitution using life cycle costing?
3. How do the tools found measure up to the selection criteria, and what improvements, if any, are suggested?

Figure 19: Research Questions

Conclusions

The conclusions drawn from this research are seen most clearly in the answers to the research questions. First, the problem as defined from the background of existing literature from chapter two is discussed. Then the research questions follow, with a summary of the results presented question by question. The tool evaluation criteria and the available tools are from chapter three and the tool evaluations from chapter four provide the information requested in the questions.

The Problem Description:

The Pollution Prevention Action Plan sets policy for reduction of hazardous materials use and waste generation at Air Force installations. The purpose of the Hazardous Material Pharmacy concept is to minimize, track, and control the ordering, storing, distributing, using and disposing of hazardous materials through effective use of single point control. Since the HMP approves all hazardous material purchases requests, material ordering is the point in the process chosen to consider alternatives. The HMP works with requesters to identify substitutes which have the minimum impact on safety, health and the environment while the purchasing procedures take into account the life-cycle costs of hazardous materials.

Selecting less hazardous material substitutions considering life cycle costing is included as an element of the Hazardous Materials Pharmacy Implementation Plan, distributed by USAF Headquarters in May 1995. However the specifics of performing that function are not described in detail. The HMP staff typically does not have the time or detailed information available to make such complex decisions for each hazardous material purchase. Resources, or tools, that may assist in making the material substitution decision attainable are both information databases and life cycle costing tools. Costing tools that prompt for appropriate cost input and calculate a material cost estimate based on the material's life cycle, assist in the comparison of materials on an equal basis. Other material comparison areas include impact on production as well as environmental, health and safety impacts.

1. What criteria should be used in selecting tools to be considered able to contribute to the pharmacy requirement?

To contribute to the material substitution requirement, the criteria for selecting tools must be able to differentiate between specific tool substitution characteristics. The Air Force goals for the substitution requirement establish the essential criteria to be used. The AF drive is to minimize material costs over their life cycles, and minimize material impact on worker safety, health and the environment. Additional criteria from the HMP users viewpoint of tool expectations both contribute to meeting the AF goal and round out the evaluation by demanding certain performance requirements from the tool.

Different sources were explored to determine the tool users viewpoint, including a previous survey of Pollution Prevention Chiefs, evaluations of tools in the literature, interviews with three Hazardous Material Pharmacy Chiefs, and personal experience starting a HMP from scratch. The resulting criteria assumed to reflect the major values of most HMP chiefs, while meeting AF goals, is presented at Figure 20.

Major Value	Attributes
Life Cycle Cost	Initial Cost Operations Cost Disposal Cost
Decision Information	Environmental Effects Occupational Health Material Substitutes Data Update Capability
Ease of Use	Simple Few Inputs No Additional Training
Tool Cost	Cost of Model Additional Equipment

Figure 20: Decision Criteria

These criteria for selecting tools seem to cover the broad decision areas and provide enough variety to be able to differentiate between the different desired tool substitution characteristics.

2. What tools are available to meet the functional requirement of hazardous material substitution using life cycle costing?

The tools identified in this research effort had to both be available to HMPs and be able to provide an informational need to the material substitution decision. The tools found to be functional and available for this evaluation resulted from past life cycle cost model studies, informational databases in the literature, and interviews with people in the field of hazardous material use reduction. The search resulted in many different types of tools with varying levels of effort, differing output, and varying degrees of applicability to the hazardous materials pharmacy material selection decision. The available tools considered in this effort are placed into the different tool type classifications in Figure 21 representing the spectrum of evaluation tools available.

Classification 1: Unit-Cost Models and Databases

- Hazardous Materials Life Cycle Cost Estimator (HAZMAT)

Classification 2: Parametric Cost Models

- Burley and Phillips Decision Support Model (B&P DSM)
- Remedial Action Cost Engineering and Requirements (RACER)

Classification 3: Project Cost Databases

- Historical Cost Analysis System (HCAS)

Classification 4: Engineering Case Studies and Reports

- EPA Pollution Prevention Information Clearinghouse (PPIC)
- AFCEE PRO-ACT

Classification 5: Project Management Systems

-Hazardous Material Procurement Action Tracking System (HazMat PATS)

Figure 21: Tool Classifications

Classifications 1 and 2 offer the greatest possibility for generating accurate cost estimates however they may be time and data intensive. Classifications 3 through 5 offer quick information on substitutions and costs that have been tried previously. All of them were currently available and able to provide needed information to the material substitution decision.

3. How do the tools found measure up to the selection criteria, and what improvements, if any, are suggested?

The summary of cost tool evaluations follows as Figure 22.

Major Values	Tools: / Criteria	HAZMAT	B&P DSM	RACER	HCAS	EPA PPIC	PROACT	HazMat PATS
Life Cycle	Initial Cost	●	●					
	Opertn Cost	●	●					
	Dispose Cost	●	●	●	●			
Decis Info	Envir Impact	○	○	○	○	○	○	●
	Occup Health	○	○	○	○	○	○	●
	Matl Subs	○				○	●	●
	Data Update			○	○	○	○	○
Ease of Use	Simple Undstd	○	○	○	○	●	●	●
	Few Inputs	○		●	○	○	●	●
	NoAdtl Tng	○	○	○	○	●	●	○
Tool Cost	NoCost Tool	●	●	●	●	●	●	●
	NoAdtl Equip	●	○	○	●	●	●	○

Legend: Is the criterion met by the tool?

● = YES ○ =LIMITED (case specific) BLANK = NO

Figure 22: Summary Evaluation of Tools

The two cost models that addressed the life cycle criteria completely were both lacking some important features in decision information and ease of use for application as a hazardous material pharmacy costing tool. Alternately, the tools without life cycle cost components were stronger in other decision information besides cost and also easier to use. No tool was strong across the board, so it appears that most tools have been developed to be for either costing or informational purposes, not both.

The criteria area that needs the most work is making decision information available for selecting alternate hazardous materials, namely listing environmental effects, occupational heath impacts, and potential material substitutes. Also lacking in most tools was the ability to update the data on which the model's result credibility is based.

The Burley and Phillips model is structured more for a pharmacy type material LCC analysis than HAZMAT that is structured for weapon system analysis. Burley and Phillips would have fared much better had the life cycle cost algorithms been computerized, because it would have improved the ease of use and tool cost criteria, making it obviously preferred to the HAZMAT model. The information clearinghouses, although not tied directly or loaded into a particular cost model, may be used to supplement the informational gaps of the cost models, such as providing any known substitutes. An alternative to using two tools to perform the task could be to load a life cycle cost model, like B&P DSM into the HazMat PATS system, making it cover most of the criteria. If the PATS tie to the supply system was made real time, then actual costs of purchase, use and disposal could be recorded forming an appropriate accounting system for tracking life cycle data.

Discussion of Results

This research effort has brought to light the fact that a simple costing tool was not found that could be quickly and easily be applied to the hazardous materials pharmacy requirement of finding material substitutes using life cycle costing. It is apparent that in the Air Force, the development of models has been directed at acquisition applications. The difference between building a major weapon system and evaluating daily processes at installations is too large of a gap in application to be able to use products for one purpose that were developed for the other purpose.

Also informational clearinghouses are effective sources of pollution prevention ideas. The challenge is making managers aware of their existence and training staff to perform effective searches. As technology attempts to make these resources more accessible and user friendly, the volume of material should become less overwhelming. Since industry is looking at life cycle or total cost accounting more seriously as a way to reduce the bottom line, the cost data tied to a particular process or function should become more readily available in clearinghouses or case studies performed to show cost reductions, filling the major cost data gap associated with those databases.

Considering that no one tool was strong across the board and that it will take some time for the data gaps in any one tool to be filled, a combination of tools may need to be used in the interim to perform hazardous material substitutions. Although having different tools for different functions is adequate to perform the task, a complete system for substitution decision information could create synergy from interactive databases and offer the convenience of one-stop shopping to the decision makers.

Areas for Future Research

Continuing efforts are possible to further the findings made here. First, the search performed for existing tools in the current academic literature identified very few tools. There may be other tools available, possibly developed by industry, that can be tailored for Hazardous Materials Pharmacy use. Also, the current use of tools in pharmacies could be extensively surveyed to see if any current procedures warrant establishment as a standard for all pharmacies. The survey could establish the extent of hazardous material substitutions actually performed by pharmacies and what procedures or tools are used to do so. The survey could also include procurement offices to see if any substitution avenues are being pursued by contract methods.

The development of a new tool for material substitution decisions that can be used in conjunction with the pharmacy material control program would be extremely beneficial. Also possible is the modification of an existing tool for that purpose.

Summary

Although hazardous material substitutions are stated in policy to be a pharmacy task, the task is not performed for every material purchase because of lack of time, resources, and specific guidance. Hazardous Material Pharmacy staff could use informational databases or cost tools to supplement their knowledge and training, standardize their substitution recommendations, and reduce their workload. The hazardous material substitution decision requires an accurate life cycle cost estimator that considers health and environmental impacts primarily, as well as being easy to use and acquire. This thesis effort found that no one tool was strong across the board, implying a mixture of tools may be needed to perform substitution decisions .

Many tools exist, but most are either not directly applicable to pharmacy operations, or require extensive user analysis with data collection efforts that take too much time. At the current time, it is only feasible for HMPs to consult information clearinghouses and other quick sources of source reduction technologies to see if any are applicable to their process. Any extensive look at substitution and the total costs is typically delayed for accomplishment by an opportunity assessment team trained to do so. Until a tool is developed that meets more of the HMP requirements, consideration should be given to changing contracting procedures to have substitutions suggested by the material suppliers who have the material information, the burden of proof, and the motivation to obtain and maintain government contracts.

Appendix A: Questionnaire Responses

Charlotte Hudson completed a thesis in 1995 titled "A Decision Tool to Optimally Select Pollution Prevention Projects within a Constrained Budget." The goal of her thesis was to develop a model that aids decision makers in selecting the best mix of pollution prevention projects. The term "best" is subjective and depends on several factors including both the costs and benefits of each pollution prevention project. To determine these factors, she sent out a questionnaire to base level pollution prevention managers. The purpose of the questionnaire was to determine the objectives important to the decision makers when selecting pollution prevention projects for their installations.

Sixty questionnaires were sent out to base-level pollution prevention managers. Thirty-three percent returned the completed questionnaire. The questions and responses can be found at the end of this appendix. For non-attribution reasons, any references to the person responding or their installation was deleted, otherwise responses are typed exactly as shown on the completed questionnaire. The question asked is in bold followed by the numbered responses of the managers surveyed. If a manager did not respond to a certain question then the number corresponding to that manager was left out completely.

For my pharmacy thesis, I needed to establish criteria relevant to the Hazardous Material Pharmacy task of selecting alternate, less hazardous materials. Since hazardous material substitution is a potential pollution prevention project, the important objectives from the Hudson questionnaire are applicable to this pharmacy decision. I used the questionnaire to tally each of the selection concern categories mentioned in the responses. The voiced concerns, in order of descending frequency of mention, include:

- Reduction of environmental impact (25)
- Meeting laws and Air Force goals (14)
- Obtaining money and justifying costs (8)
- Hazards to human health (5)
- Ability and desire to change process (5)
- Operational performance (5)
- Manpower (4)
- Lifetime of improvement (2)
- Liability (1)

Several of these lesser mentioned concerns are related to others and can be grouped into three major concern areas of hazard impact, cost, and change of operations issues. For example, reduction of environmental impact and hazards to human health were grouped together because many of the questionnaire respondents stated they considered human impacts strongly but often as a member of the affected environment. Combining these results shows that the majority of decision makers have three main objectives when selecting projects: 1) minimizing operation's impact on human health and the environment; 2) obtaining funding with validated cost estimates in order to meet laws and goals; and 3) ease of implementing the change into the process. Decision makers most often struggle with balancing between these objectives.

QUESTIONNAIRE AND RESPONSES FROM POLLUTION PREVENTION

PROGRAM MANAGERS:

Questionnaire-

1.a. When selecting pollution prevention projects to implement, is your choice based solely on payback period?
1.b. If not, what other factors do you consider?
1.c. If yes, why do you not consider other factors?

2.a. Do you feel the payback period is an adequate measure for choosing the best pollution prevention projects?
2.b. Please state why or why not.

3.a. Do you feel that using another method besides payback period would result in significant changes in pollution prevention projects chosen?
3.b. What other factors would you like to see used to select projects?

4. Does your budget limit the number of projects that you implement in a given year?

5. If you were to choose projects based on environmental benefits do you (would you) consider mainly human or ecological effects of the waste eliminated?

6.a. Is manpower a major consideration when choosing projects?
6.b. Please state why or why not.

Responses-

1.a. When selecting pollution prevention projects to implement, is your choice based solely on payback period?

1. No

2. In some cases, no. Recycling is the most prevalent case that comes to mind. Recycling cures a lot of ails, yet "payback" may never be attained.

3. No

4. No

5. No

6. No, Payback period is a means of selling the project to senior staff, but the "bottom line" is what waste streams are we trying to eliminate and what impact do these waste streams have on the installation and the environment.

7. No

8. No

9. No

10. No

11. No

12. No

13. No

14. No

15. No

16. No

17. No

18. No

19. No

20. No

1.b. If not, what other factors do you consider?

1. Anticipated or existing compliance with regulations or policies are also driving factors. Pollution prevention is costly and to solely base implementation on payback can severely limit meeting requirements.

2. Doing what is "environmentally smart".

3. Equipment performance, contractor performance, manpower requirements, feasibility

4. Cost of project, needs of customers

5. Benefits to the environment such as hazardous waste reduction

6. Elimination of waste streams, liability, manpower requirements, funding, compliance.

7. I consider these additional factors - IMPACTS on: hazardous waste and solid waste generation; water quality and EPA 1 7/ODC reduction goals.

8. I do a cost/benefit analysis; will the project make a process more efficient? I also give the project the common sense test; Is the project feasible, even with a short payback period; and.how easy it will be to implement and maintain after purchase.

9. Desire of the shop/organization to use/implement is very important. Some people won't change so we go firsts with those that will.

10. The needs of different squadrons--where more waste will be recycled. e.g. antifreeze recycler instead of stencil machine.

11. How much will it reduce a Hazardous Waste stream is my most important factor,

12. Total quantity of waste to be reduced, hazards associated with the waste

13. Environmental impact such as amount of waste or emissions reduced.

14. Desire of customer to implement change, feasibility of actually implementing the project, consider economics from standpoint of one large project versus several small projects, total picture, reduction in pollution with money available

15. What will give me the greatest hazardous waste, solid waste, or hazardous material generation reduction; where we sit at the present time in reaching our goals in reduction; is it a level P1,P2 or P3 project.

16. Value of the project in meeting environmental priorities

17. Safety, health, environmental benefits, reduced risks, public response

18. Is project legal under AFI 32-7080?; Does project eliminate ODC's or EPA-17's?; Will I get funding?; Can we reduce hazardous waste stream or solid waste stream?

19. Volume or amount of pollution prevented; efficiency of new process versus the old process; compliance with existing or future regulations.

20. Process change: Will the project eliminate use of an EPA 17 toxic? Minimize hazardous waste production or minimize solid waste? Also: availability of the unit to operate equipment or work with process change: How well accepted will the change be?

1.c. If yes. why do you not consider other factors?

N/A. All said "no".

2.a. Do you feel the payback period is an adequate measure for choosing the best pollution prevention projects?

1. No, not in itself
2. No
3. No, but it is mandated
4. No
5. No
6. No

7. No

8. No

9. It is adequate mainly for technical review. In the real world you must also meet commander and HQ desires.

10. Overall yes

11. No

12. From an economic standpoint, yes. From an environmental standpoint, not necessarily.

13. No

14. No

15. Payback period is only one consideration

16. No

17. No

18. No

19. It is adequate if it can be done with accuracy. This is not always the case.

20. No.

2.b. Please state why or why not.

1. Cost payback should be a factor but not the sole factor

2. As a base competing against others for funds, unless I can show payback I will not get the funding.

4. Not all projects have a payback

5. It needs to be a part of the decision process. However, many of our pollution prevention initiatives would ever happen if they were only measures of payback period.

6. Payback period is only one aspect of a P2 project in some instances it might not even be a consideration due to a change in the law which requires compliance regardless of cost. If we are truly complying with the intent of existing federal and state environmental laws payback period can not be the only measure.

7. Payback period is not good as a sole factor in determining what projects to select because, too often, process changes needed to meet goals don't necessarily lend themselves to quick or tangible payback periods, e.g. base-wide recycling, which reduces solid waste generation, does not have a tangible payback for a reserve base.

8. A project can have a I month payback period, but still might not be feasible, consider the ease of execution of a project! The project must also be necessary and meet P2 criteria.

9. Simple payback does not always peak the interest of users and managers. You have to be a good salesman!

10. It helps when it comes to wise spending of your P2 money,

11. A measure may actually cost money, but, if it reduces or eliminates a hazardous waste stream it is still a valid measure.

12. We certainly cannot ignore economics when making critical decisions on how to invest our resources. However, we often fail to consider the entire picture when calculating payback period. For example, when we consider the use of solar energy to reduce our demand for fossil fuels, solar technology is almost always more expensive.

The use of petroleum has hidden costs, however, which must be considered; costs such as rem diation of petroleum spills. Another drawback to using economic payback is it fails to consider intangible benefits to human health and the environment such as improved air quality, decreased exposure to toxic substances, etc.

13. It has a built in bias for inferior quality. Internal rate of return is a better form of economic analysis. But economics alone do not tell the whole story. Environmental impact and safety considerations are vital parts of the equation.

14. Because some projects may reduce EPA 17 for example but have little or no payback.

15. It is only one parameter

16. Sometimes the payback period may be longer but the ultimate gain in reducing pollution is better than projects with short payback periods. Also, some projects may not be done with a shorter payback period regardless of funding availability due to the engineering involved.

17. Pollution prevention has many intangible benefits that must be used to help make a decision. The most cost effective project may not be the best project.

18. Often times pollution prevention projects have no defined payback. For example, here in the Northeast, recycling is a losing ($$) proposition. However, a strong recycling program provides good PR with the local community and state.

19. It is adequate to give you a quick check to see if you have a good project or whether you will be wasting lots of time and money with little benefit.

20. As stated above, users are the ones who will live with the PP changes. If they are not willing to operate a solvent distiller then we need to come up with a different alternative regardless of the payback period.

3.a. Do you feel that using another method besides payback period would result in significant changes in pollution prevention projects chosen?

1. Yes. It would open up other project opportunities normally eliminated because of long payback. Would give bases more flexibility in tackling base concerns.

2. Yes.

3. Yes

4. Yes

5. Yes

6. Not at this time since payback period isn't our only measure

7. Yes

8. Not significant changes, but would enable managers to look further into the future effectiveness of a projects, beyond the payback period.

9. Other logical, though out processes will get similar choices, but sometimes logic does not come into play!

10. Not significantly

11. Yes

12. Probably not. Most P2 projects with high payback periods tend to enhance protection of human health and the environment.

13. Hard to say. Based on my observations, payback has relatively little to do with what gets funded. IT depends more on the ability of the program manager to advocate for resources form HQ, the speed with which funds can be obligated, and the degree to which the project can be tied to some pet project of HQ (e.g. Hazmarts) or some political hotbutton (e.g. ODCs).

14. Yes--in some cases.

15. Payback is not the only consideration

16. Yes

17. No single method should be used. All issues should be addressed

18. Not under the present system HQ uses.

19. Yes

20. No. Currently at base level projects are chosen based on EPA 17 or waste minimization opportunities and on Tech Orders--driven requirements

3.b. What other factors would you like to see used to select projects?

1. Quantity, quantity/unit cost, and risk associated with all P2 programs. (e.g. Iarge volume chemical reductions, health concerns, etc.)

2. Place more emphasis on environmental benefits; pollution prevention, energy conservation, waste reduction...in other words getting back to the basics. We've spent a lot of money getting into the environmental mess we are in so we must spend money to get us back on track.

3. Performance, waste minimization, pollution reduction

4. Customer needs, and percent of waste reduction

5. Waste reduction, worker safety

7. IMPACT measurement on wash generation, water quality, air quality and environmental goals.

8. Time-Life span of a project, user friendliness, idiot proof or easy to maintain, ease of purchase and implementation, Is the project a significant benefit to an organization and the Air Force?

9. Work efficiency improvement

10. You just have to know what will benefit the base the most--Amount of waste diverted.

11. Hazardous Waste reduction

12. Ability of project to help base meet AF goals. A project which may drastically reduce hazardous waste generation (therefore help us meet 50% reduction goal) may not have a high payback period.

13. Environmental impact and safety considerations.

14. Consider pollution reduction percent versus money saved.

16. Long term gains in P2 versus short-term smaller gains; spending more up front on P2 to eliminate the source rather than spend a lesser amount on compliance.

18. Elimination of TRI chemical purchases, reduction of hazardous waste or solid waste streams.

19. The factors I listed above.

20. Deletion of EPA 17 requirement

4. Does your budget limit the number of projects that you implement in a given year?

1. Qualified yes. Essentially the limiting factor is what Headquarters is willing to fund.
2. Definitely. For example I asked for $1.6 million for FY 96 and I am receiving $294K. Talk about limits.
3. Yes
4. Yes
5. Yes
6. Not significantly, but it would depend on requirements by the other environmental programs.
7. Of course my budget is limits the number of projects I implement in a year - that is why the projects are prioritized.
8. Yes, big projects (>$ 100,000) are almost never funded, even if they are justified.
9. No, our PP budget is very healthy at this time.
10. Yes
11. Yes
12. DEFINITELY. Even projects with short payback periods are frequently not funded due to budget constraints.
13. Somewhat
14. We do not receive a budget. Projects are approved by MAJCOM on a case by case basis. They give specific amounts for specific projects.
15. HQ funds projects, but their budgets limit the number of projects we implement.

1 6. Yes

17. Yes, the wish list is always much larger than the pocketbook.

18. My budget always limits the number of projects I do each year. We try our best to "think of" projects that fall within the rules set by our HQ, but are not always successful in getting everything funded.

19. Yes

20. Yes, out of 990K programmed only got funding for 75 K for FY 95.

5. If you were to choose projects based on environmental benefits do you (would you) consider mainly human or ecological effects of the waste eliminated?

1. That is a loaded question. We have to do both

2. My first thoughts are to do what is ecologically safe and since humans are a part of that ecology they would only benefit.

3. Both

4. Both factors should be considered

5. Human effects

6. Ecological would probably be the primary but it depends on the type of waste stream. Consider the fact that ecological in the long term factors in human consideration. The only exception to this would be if I could eliminate a particularly hazardous process that was a clear and present danger to humans.

7. When choosing P2 projects, both human and ecological effects of the wast stream eliminated are considered equally. If these are the only factors remaining to decide between two projects, then impacts on human effects would have a higher priority.

8. You have to consider both, but when it comes right down to it I am worried about human effects first.

9. Human first, ecology second, but both are important--but people come first!

10. Human

11. Human

12. I would consider both (probably equally)

13. Human and ecological factors are inextricably linked. However, I would put more weight on those projects which had the most direct benefit on humans.

14. No. I would consider the P2 goals like reduction of EPA 17 or hazardous waste generated and the possibility of reducing those.

15. A combination of both

16. I would consider both equally. Whatever affects the ecology will ultimately affect humans.

17. I wouldn't lean one way or another. All projects should be weighed on their own merits with proper attention given to all effected areas.

18. Ecological (there are others who consider the human effects)

19. No

20. Either: waste eliminated will not go to an incinerator/landfill which harm both humans and earth.

6.a. Is manpower a major consideration when choosing projects?

1. No

2. No

3. Yes

4. No

5. Yes

6. Yes

7. No

8. Yes

9. Yes, many times we don't have time to evaluate projects well, we go with "gut feeling" more than hard numbers.

10. Yes

11. Yes

12. Yes

13. Yes

14. No, but it is a factor.

15. Yes

16. No

17. Yes

18. Yes

19. No

20. Yes

6.b. Please state why or why not.

1. Most projects are done by contract. The shear number of projects to be manages could be limiting factor since base personnel normally are the OPR for the project for their individual organization.

2. I attempt to do all in my power to choose projects necessary for the base. I will pull the entire base populace to get the project complete.

3. In order to get the project done effectively, you must have trained, knowledgeable, dedicated and committed people to do it.

4. Each project must be weighed separately--other factors must be considered.

5. Many of these projects require a significant amount of manpower to implement.

6. We are manned mostly by civilian employees. Any P2 project that would require an increase in man hours would require the hiring of another position is a significant problem.

7. Most projects involve process changes. Any chosen solution to process change must have minimal impact on manpower. The only exception I have come across pertains to recycling solid wastes - lack of manpower results in contracted services.

8. The P2 shop is basically tow people and P2 is a broad scope job, it is very difficult to incorporate all aspects into projects funding with limited manpower.

9. Pressure to get things bought now so we don't lose the money!

10. We have only one person doing P2 half of the time.

11. Manpower is very limited and I can't pick a project that would make things worse.

12. Some projects require intense investigation prior to being implemented. IT can be difficult to find the time to adequately investigate P2 projects which may significantly reduce waste generation.

13. When manpower ceilings are in effect you cannot undertake a project that requires extensive manpower no matter how much money it saves or how much money you have to spend on the project, or how much it will benefit the environment.

14. You need personnel to conduct OA's and to deal with the MAJCOM programmers.

15. If you are buying a new piece of equipment - consideration has to be given to installation and operating of the equipment.

16. This office handles mainly funding and the contract actions. As a management organization we are staffed to handle this type of work. If this organization actually performed the research, then manpower would be a limiting constraint. If funding weren't a constraint, then we probably wouldn't limit the number of projects undertaken in a given year.

17. You shouldn't bite off more than you can chew. It is very unwise to solicit funding for something you can't implement.

18. IF I had more "bodies" my office could manage more projects in greater detail. No one wants to give up bodies for PP. As it stands right now about 1/5 of my non-facility repair FY95 budget is tied up in contract employees.

19. Manpower is a major consideration when prioritizing projects, but not for choosing projects

20. If a shop has no time/person/training to operate a recycler/distiller etc. they will just drum up the wastes and let the recycler sit unused.

Appendix B: Decision Analysis Model

Evaluating Existing Hazardous Materials Cost Tools to assist

in Hazardous Materials Substitution Decisions

Model Formulation

This problem is a multiple criteria decision problem due to the several, often conflicting, qualities that must be evaluated to rank the tools, including life cycle cost models and databases, for use in an AF Hazardous Material Pharmacy. The multicriteria methodology includes development of decision criteria, identification of attributes desired, and incorporation into a multivariate utility function that forms the basis of a decision model. The steps of the decision analysis process described by Clemen, are outlined in Figure B-1. Steps one and two are covered in the thesis. Steps three and four are described in this appendix as they pertain to the tool decision model.

Step 1. Identify the Problem Step 2. Identifying the Objectives and Alternatives Step 3. Decompose and Model the Problem Step 4. Choose the Best Alternative

Figure B-1: Decision Analysis Steps by Clemen

To ensure a smooth presentation of the model, the pertinent data from the thesis will be briefly restated here. For example, the objectives that guide a decision maker when faced with a hard decision can be referred to as criteria. These are presented next.

The Pharmacy Chief at Wright-Patterson AFB, Captain Rebecca Robinson, participated in a thorough decision analysis investigation of the drivers of a costing tool selection, forming the value tree at Figure B-2. The major objectives are labeled as decision values and the measurable sub-items are called attributes.

Values	Attributes
Use Life Cycle Cost	- Initial material cost - Operations cost - Disposal cost
Decision Info	- Material environmental effects - Occupational health effects - Substitute materials suggested - Data/Cost can update
Ease of Use	- Simple - Few inputs required - No additional training
Tool Cost	- Availability/Cost to get - Additional equipment

Figure B-1: Value Tree

Completing Step 2 is identifying the alternatives. The alternatives, or tools that are considered for evaluation, currently consist of seven models, databases or other tool. The tools include the Hazardous Materials Life Cycle Cost Estimator (HAZMAT) model, Burley and Phillips Decision Support Model (B&P DSM), Remedial Action Cost Engineering and Requirements (RACER) model, Historical Cost Analysis System (HCAS) database, EPA Pollution Prevention Information Clearinghouse (PPIC), AF Center for Environmental Excellence PRO-ACT Information Line, and the Hazardous Material Procurement Action Tracking System (HM PATS). Each of the tool alternatives are evaluated against the criteria using the evaluation performed for my thesis. The tools were evaluated, as in Figure B-3, based on three levels of meeting the criteria from:

- Yes, it meets criterion (represented by a filled circle~ eval score of 3)
- Limited meeting of criterion (represented by an empty circle~ eval score of 2)
- No, doesn't meet criterion (represented by a blank~ eval score of 1)

Major Values	Tools: Criteria	HAZMAT	B & P DSM	RACER	HCAS	EPA PPIC	PROACT	HazMat PATS
Life Cycle	Initial Cost	●	●					
	Opertn Cost	●	●					
	Dispos e Cost	●	●	●	●			
Decis Info	Envir Impact	○	○	○	○	○	○	●
	Occup Health	○	○	○	○	○	○	●
	Matl Subs	○				○	●	●
	Data Update			○	○	○	○	○
Ease of Use	Simple Undstd	○	○	○	○	●	●	●
	Few Inputs	○		●	○	○	●	●
	NoAdtl Tng	○	○	○	○	●	●	○
Tool Cost	NoCost Tool	●	●	●	●	●	●	●
	NoAdtl Equip	●	○	○	●	●	●	○

Figure B-3: Summary Evaluation of Tools

To model the problem, Step 3, the decision criteria the basis of the decision model. The structure of the cost tool decision is more easily depicted by the use of Decision Processing Language (DPL) which can show an influence diagram of the criteria influences on the overall decision. The model to evaluate the tools for hazardous material substitution is at Figure B-4. The choice or decision to be made is represented by the square shape, which decides between the seven tools being evaluated. This influence diagram, captures the uncertainty, represented by the oval, of what material type that may be used on an Air Force base. Currently 3 major material types are considered to be representative of the field. These include chemicals, paints/adhesives, and solvents. The probabilities entered in the model, based on the decision maker's materials use, were .50, .33, and .17 respectively.

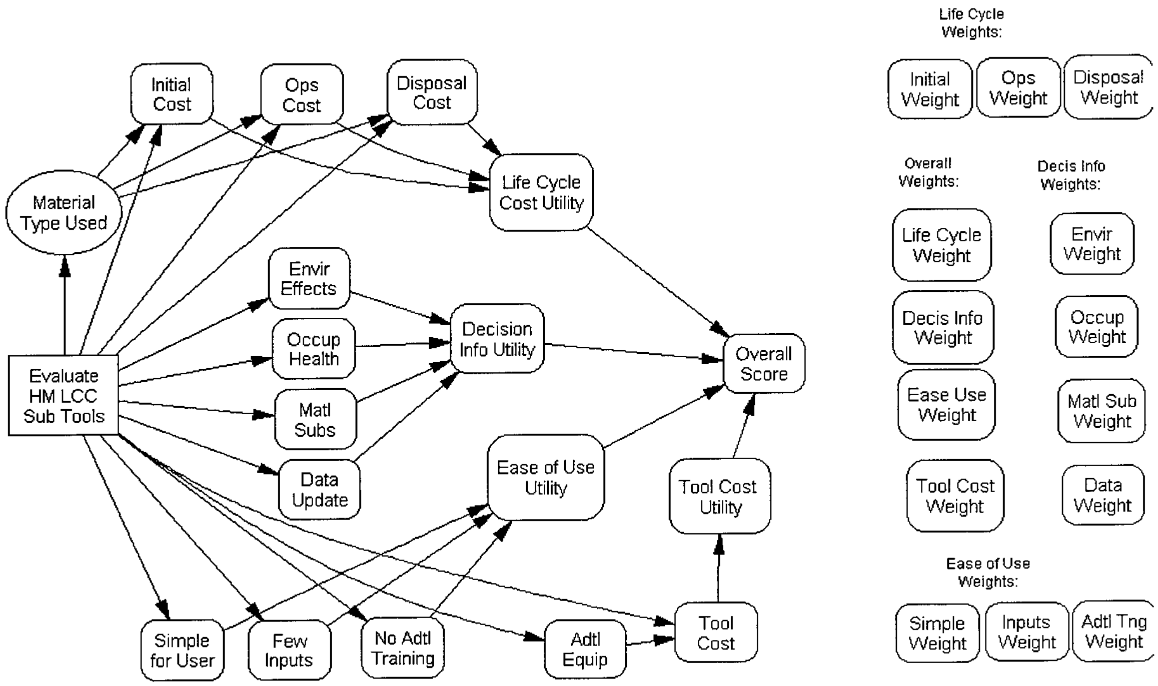

Figure B-4: Decision Influence Diagram

This model calculates an overall score for each tool. Note the four utilities that factor into the overall score are the four major values. Each criterion node is incorporated into one of the four multivariate utility functions. Due to assuming mutual preferential independence, but not necessarily utility independence between criteria, linear additive utility functions were used in the model. Each of the seven tools individual performance from the evaluation is entered, on a scale of one to three, into each criterion node. A sample of how the criteria evaluations were entered into the criteria value nodes in the DPL model follows in Figure B-5 for the Few Inputs criterion.

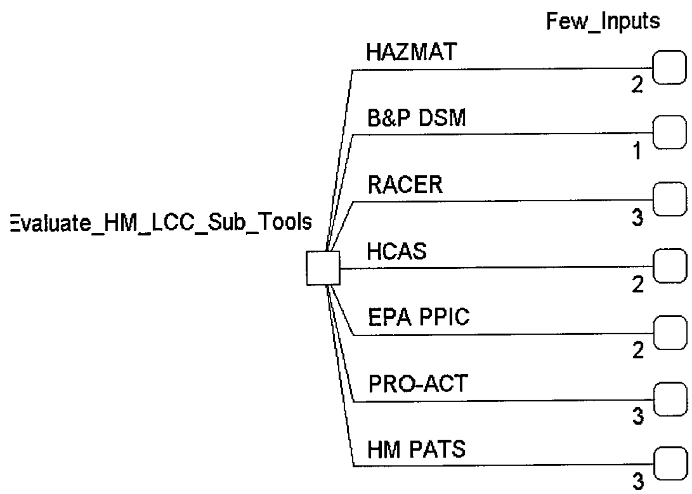

Figure B-5: "Few Inputs" Tool Evaluation Data

The tool evaluation information for each criterion is aggregated into one of the four utilities based on the weight of the criterion's relative importance to the other criteria in the same utility, or major value. Then each utility is rolled up into the overall score based on the weight of that utility in respect to the decision to be made. From a survey with Robinson, the decision maker, the weights of each criterion based on its respective value to the decision outcome are:

Life Cycle		Decision Info		Ease of Use		Overall	
Initial	.10	Envir Effect	.15	Simple	.40	Life Cycle	.30
Ops	.60	Occup Hlth	.15	Inputs	.40	Character	.30
Disp	.30	Matl Subs	.40	Adt Tng	.20	Ease Use	.30
		Data Update	.30			Tool Cost	.10

Model Formulation Solution

The output of the model, or proposed solution, gives a recommended decision policy to choose a substitution tool that receives the highest score. The scoring is driven by the utility equations, or weighted linear combinations of the attributes. The additive form of the utility function was used, with preferential independence assumed, due to not having surveyed for mutual preferential and utility independence. Based on using a linear combination of the additive utility functions, the resulting overall ranking of the tool alternatives follows as the decision policy in Figure B-6.

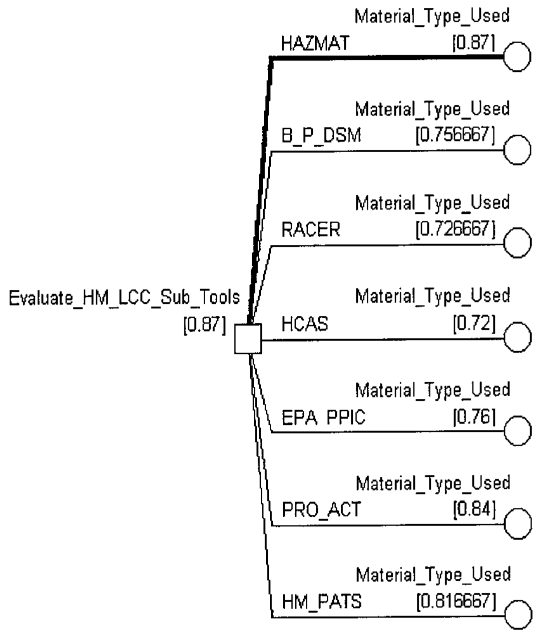

Figure B-6: Initial Decision Policy

The scoring resulted in HAZMAT receiving the highest value, followed closely by PRO-ACT and HazMat PATS. These are the models that Becky Robinson would find most useful and worthy of closer analysis, according to her criteria weighting. The particular qualities and evaluations of these tools are discussed in my thesis, Chapter Four.

Conclusion

The complex evaluation problem of cost tools to use for hazardous materials selection decisions can be modeled using decision analysis. The model constructed in this project uses a decision maker's values, as responded to a survey. Some result ordering may have been affected by the complexity of the decision survey or misunderstanding of the questions by the decision maker. Although other hazardous materials pharmacies have similar needs, their actual surveyed values could differ enough to change the resulting tool ordering. Although the Pharmacy Chief, according to this model, would rank the tools in the following order, the narrow range of scores suggests the need for a wider evaluation scale to better differentiate between the tools. Also, limiting the tools evaluated to the few most promising, rather than trying to be comprehensive will produce more accurate results. Because of the need to refine the model and the data put into it, the tools recommended by this model are not written into the text of my thesis. Instead, each decision maker looking for tools will get a picture of different tools strengths and weaknesses from the tool evaluation summary table. Armed with information on what is available, they will be in a position to make a more informed decision on what tool or combination of them to try when needing material substitution information.

<u>Initial Results</u>-

- HAZMAT	.870
- PRO ACT	.840
- HM PATS	.817
- EPA PPIC	.760
- B P DSM	.757
- RACER	.727
- HCAS	.720

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Vita

Captain Rowene J. Resler was born on 5 December 1966 in Albuquerque, New Mexico. She graduated from Hampton High School in Hampton, Virginia in 1984 and entered undergraduate studies at Rensselaer Polytechnic Institute in Troy, New York. She graduated with a Bachelor of Science degree in Mechanical Engineering and received her commission from the Unites States Air Force in May 1988.

Her first assignment was at Goodfellow AFB, TX, as a design engineer. In 1991, her second assignment was at Osan AB, Republic of Korea, as a REDHORSE project manager. Upon return to the United States in 1992, she attended Squadron Officers School at Maxwell AFB, AL. Her third assignment was at Los Angeles AFB as deputy base civil engineer and specifically directed the environmental flight. In May 1995, she entered the Engineering and Environmental Management Program at the Graduate School of Engineering, Air Force Institute of Technology. After graduation, she will be assigned to Beale AFB, CA.

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EVALUATION OF HAZARDOUS MATERIAL LIFE CYCLE COST TOOLS FOR USE IN AIR FORCE HAZARDOUS MATERIAL PHARMACIES

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Recent trends of expanding environmental awareness and a shrinking defense budget challenge Air Force managers faced with the task of reducing environmental impacts associated with current operations. The Air Force has specific environmental goals that the Pollution Prevention Program addresses. One pollution prevention initiative, aimed at reducing operational environmental impact, is the Hazardous Material Pharmacy (HMP) concept.

This research focuses on evaluation of various tools that assist in the selection of hazardous material substitutes. Substitute material consideration is a function of the HMP when a hazardous material is requested for purchase and use in a current base operation. The substitute material decision is complex, involving identification of potential substitutes and then comparison of factors, such as cost, performance, and environmental effects, between the potential substitute and the material being requested. Various tools such as life cycle cost models, databases, and other information services can provide assistance to HMPs making substitution decisions.

The evaluation of tools is based on performance as well as functionality of the tool. Performance of the tool, in providing information to the decision maker, considers categories such as life cycle cost and environmental effects, while tool functionality considers items like ease of use. Although this research specifically addresses HMP requirements, the evaluation can be applied to any operation that makes hazardous material substitution decisions.

Hazardous Materials, Substitution, Pollution Prevention, Life Cycle Cost, Decision Analysis 115

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