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DEVELOPMENT OF INVENTORY MODELS IN SUPPORT OF THE HAZARDOUS MATERIAL MINIMIZATION CENTER CONCEPT AT FISC, PUGET SOUND

by

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December, 1994

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ABSTRACT

This thesis presents an in-depth analysis of the proposed Hazardous Material Minimization Center Concept projected to be prototyped in the Puget Sound, Washington area in an effort to optimize inventory levels. It examines preexisting Hazardous Material operations at NAWS Point Mugu, CA, and five sites in the Puget Sound, WA area in an effort to incorporate the positive qualities into the prototype. The thesis analyzes the suitability of the Hazardous Material Inventory Control System (HICS) to generate sufficient data for inventory optimization and provides an analysis of data generated by the HICS system at the Point Mugu operation. Additionally, it examines components of and potential forecasting methods for demand and lead time and provides an analysis of the variable inventory management costs associated with operating a Hazardous Material Minimization Center including ordering, holding, disposal, backorder and transportation costs. This information is used to develop two mathematical inventory models which can be used to determine reorder points and order quantities to minimize total variable costs for a given level of customer service. The next research step is to conduct a pilot study involving one or two established customers in an effort to begin refinement of these forecasting and inventory modeling techniques.

TABLE OF CONTENTS

I. INTRODUCTION

A. THE PROBLEM

Since the inception of hazardous material management, every command has been locally managing their hazardous material inventory and, as a result, the collective Navy organization has held excessive hazardous material inventory and has disposed of an unreasonable amount of hazardous material and waste [Ref.1:p.1-1]. As a result of rising disposal costs and environmental constraints on hazardous material usage, various organizations within the Navy have begun regionalizing hazardous material management in an effort to minimize disposal costs and provide more awareness to the users of the material of the inventory assets available for their use and to take advantage of stock consolidation savings. The concept of regionalizing is known as the Hazardous Material Minimization Center Concept. The first one is planned for the Puget Sound, WA area.

The Hazardous Material Minimization Center Concept features an administrative center, or hub, serving outlying smaller centers, or nodes, who actually hold the physical inventory. The hubs are located in conjunction with the Fleet and Industrial Support Centers (FISCs). The number of smaller centers may vary, depending upon the number of customers within the FISC's region of responsibility. For example, FISC Puget Sound, WA, would control centers at Whidbey Island, Keyport, Bangor, and Puget Sound Naval Shipyard. To minimize inventory costs for a given level of service to the customers, an effective inventory management system must be developed and implemented.

At present, these inventories are being managed by several different "best guess" inventory management systems. For example, Naval Air Weapons Station (NAWS), Point Mugu utilizes a Hazardous Material Inventory Control System (HICS) database system. However, this system only controls the flow of material and not inventory levels. Unfortunately, none of these various systems has any capability for mathematically optimizing the inventory levels.

The envisioned Hazardous Material Minimization Center Concept is intended to consolidate inventory management of all hazardous material within a given geographic area in an effort to minimize the total annual variable costs associated with managing the Navy's hazardous material.

B. THESIS OBJECTIVE

The purpose of this thesis is to develop an inventory model to optimize Hazardous Material inventory levels associated with the Hazardous Material Minimization Center Concept.

C. RESEARCH QUESTIONS

This study addresses the following questions:

1. Is the regional concept of Hazardous Material Minimization Center Concept appropriate for managing Hazardous Material?

2. How does the envisioned system compare with systems currently in place?

3. Does the HICS database system provide all of the necessary information to effectively evaluate/monitor use, reuse, and disposal of Hazardous Material?

4. Is demand deterministic or probabilistic, what are its components, and can it be effectively forecasted?

5. Is lead time deterministic or probabilistic, what are its components, and can it be effectively forecasted?

6. What are the costs associated with operating a regional Hazardous Material Minimization Center?

7. What is the best inventory model to minimize costs and achieve desired levels of customer service?

D. SCOPE OF THE STUDY

The thesis focuses on the Hazardous Material Minimization Center Concept in place at Point Mugu, CA, and the extension of that concept to a regional level within the Puget Sound, WA area. Two theoretical inventory models are developed as possible alternatives to aid in the inventory management of hazardous material at the regional level. The models consider hazardous material in "A" condition and in a condition which is satisfactory for reuse. The models do not consider by-products of hazardous material usage such as paint brushes, oily rags, and waste products. Insufficient data precluded testing of the models.

E. METHODOLOGY

We began our study with visits to Point Mugu, CA, and the Puget Sound, WA area. These visits allowed observations of existing HAZMAT operations and discussions with personnel to gain an understanding of current systems in operation and the need for inventory management model development. The study then moved to a thorough examination of the demand and issue data recorded by Point Mugu from January 1991 through June 1994. While the data were plentiful, they were not complete enough for detailed inventory modeling. As a consequence, we decided to develop two theoretical models, based upon continuous and periodic inventory review systems, that embellishes the Wilson Economic Order Quantity model and the Silver-Meal heuristic. In the development of these models, we considered all relevant costs, components of demand and lead time, and forecasting of demand and lead time.

F. THESIS OVERVIEW

The thesis is divided into eight chapters. Chapter I presents the problem, states the objective of the thesis, research questions and methodology, and previews our research methodology. Chapter II discusses the background of the Hazardous Material Minimization Center Concept and current efforts within this field. Chapter III examines the HICS database and its usefulness. Chapter IV discusses and offers potential solutions to the problem of forecasting the demand rate and lead time. Chapter V examines the relevant costs associated with the Hazardous Material Minimization Center Concept. Chapter VI presents the development of two Hazardous Material Inventory Models. Chapter VII shows examples of the inventory models. Chapter VIII presents a summary of the thesis efforts, conclusions from the research, and recommendations for further data collection and analysis of the inventory problem.

II. HAZARDOUS MATERIAL MANAGEMENT

A. BACKGROUND OF HAZARDOUS MATERIAL MANAGEMENT

The Navy Hazardous Material Control and Management Program is established by OPNAVINST 4110.2. The program defines uniform policy, guidance and requirements for life-cycle control of Hazardous Material used by the Navy and directs that controls be established to reduce the amount of Hazardous Material (HAZMAT) used and the amount of Hazardous Waste (HAZWASTE) generated. [Ref.1:p.1-1]

To achieve these results Naval Air Weapons Station (NAWS), Point Mugu, California, initiated the Consolidated Hazardous Material Reutilization and Inventory Management Program (CHRIMP) which strives to achieve life-cycle control and management of HAZMAT and HAZWASTE [Ref.1:p.1-1]. While Point Mugu is not the only pioneer in this effort, they have achieved the most significant progress.

B. PRE-1991 HAZARDOUS MATERIAL OPERATIONS

Prior to 1991, hazardous material was controlled on a local level throughout the United States Navy. Controlling on a local level meant that individual shops and work centers within an organization determined their hazardous material requirements, ordered the appropriate amount in an effort to meet these requirements, established their own safety levels, and disposed of excess material in accordance with their own command policy. The result of this system often led to excess material on hand, excess disposal costs, and serious over stockage of hazardous material at all levels throughout the Navy. The potential for costly environmental violations this excess material represented was enormous.

C. ORIGINATION OF THE REGIONAL HAZARDOUS MATERIAL CENTER CONCEPT

In December of 1990 it was decided by NAWS Point Mugu to adopt and implement a basewide hazardous material program. The implementation was prompted by the increasingly stringent requirements imposed on the station by the Environmental Protection Agency (EPA) which, because NAWS was in non-compliance with regulations, resulted in several monetary fines on the station. An added influence was the requirement that all government facilities abide by regulations imposed on the civilian sector. Government facilities had been previously exempted because they were immune to the regulations. The Point Mugu HAZMIN Center opened for business in January of 1991. [Ref.2]

D. IN-DEPTH EXAMINATION OF THE POINT MUGU OPERATION

1. Implementation

When Point Mugu elected to implement this new system they decided they would bring customers online on a gradual basis. They started by consolidating HAZMAT stored at eight locations within the aviation maintenance department. First, HAZMIN Center representatives met with the prospective customer and explained the purpose of the operation. If it was agreeable to the prospective customer a Memorandum of Understanding (MOU) was developed. The MOU was a simple document that formalized the agreement between the HAZMIN Center and the customer. It listed the responsibilities with regard to the requisitioning, storage, and issue of new and used HAZMAT. [Ref.1:Appendix XI] Once the MOU was signed, the customer's material was consolidated and moved to the HAZMIN Center warehouse. At the warehouse it was cataloged, tested for condition, and, if usable, was placed on the shelf and became available for issue to any command requesting the item. To induce acceptance of this program the customer was given a monetary credit for the amount of material when the collected material had a remaining shelf-life of six months or more. If material was no longer usable upon receipt by the warehouse the material was disposed of in accordance with current environmental regulations. The facility repeated this procedure for every command that joined the HAZMIN Center. [Ref.2]

Point Mugu brought new customers on line at a rate of two to three per month until the base was fully implemented. The system is founded on customer service. The HAZMIN Center verbally promises 45-minute on-base delivery from receipt of a customer order until the customer has the goods in hand. A database was designed and built called the Hazardous Inventory Control System (HICS) for use with this program. HICS maintains a running inventory of all material within the Center, records issues of material, maintains control with a bar-coded tracking number, and contains a database of over 40 files to generate all necessary reports. The database will be discussed in detail in Chapter III. [Ref.2]

Upon implementation the HAZMIN Center received a vacant building on Point Mugu and converted it into a storage center. Besides dealing with hazardous material they also controlled the base recycling program for both paper and aluminum. [Ref.2]

2. The Current System

Point Mugu has over 80 customers within the umbrella of the system. Additionally, they have installed 40 Hazardous material lockers throughout the base. These lockers are used as a storage location for two types of material: material required for immediate use by the command and waste (separated by waste stream). Immediate use is defined as an item that will be required within five working days. If an item will not be used within this five-day period the item must be returned to the HAZMIN Center for reuse. These lockers are reviewed daily by Center personnel and waste is returned to the Center for disposal. Waste disposal is under contract with a civilian waste disposal firm. [Ref.2]

The Center stores and issues two types of material: "A" condition and cost avoidance (CA). "A" condition material is new material whose seal has not been broken or has been received through the supply system. Cost avoidance material are items that have been returned to the Center through initial enrollment by a command or material that was issued to a command, was not completely used up, and subsequently has been returned to the Center. Cost avoidance material is issued free of charge to the requesting command and "A" condition material is issued at standard purchase price. If the material is cost avoidance material whose shelf-life has expired and cannot be extended, the last command holding that item is billed for the cost of disposal. All "A" condition material and disposal costs of cost avoidance material are billed monthly to the respective commands. [Ref.2]

To obtain material from the Center a customer has to phone or appear in person at the Center with their request. A clerk at the Center will ask the customer what is needed by National Stock Number (NSN) or, if unavailable, by military specification. Once it is determined that the customer is an authorized user and that the item is on hand, the customer will be queried on the quantity needed. If only cost avoidance material is on hand, the customer will be asked if that will fit his needs. If material also exists in "A" condition the customer will be given the choice of either one. After this determination, the clerk will print the bar-code and the receipt document and storeroom personnel will locate the material and deliver it to the requesting command within the 45-minute time period. After-hours requests and deliveries are handled by duty personnel who can be reached via a pager. [Ref.2]

If a customer orders material that is not held in stock, the HAZMIN Center automatically directs the request to the base supply department. The base supply department has, until recently, maintained a buffer stock of items for issue to the HAZMIN Center based on the UADPS-SP inventory model. The base supply department issues the material to the Center who, in turn, issues the material to the customer. If the base supply department does not hold the material the goods are immediately ordered by the Center via the base supply department using the customer's priority and Force Activity Designator (FAD). [Ref.2]

Open purchase items are also requested by users of this system. Open purchase items are those items not identified by national stock number. When a customer requests these items the clerk attempts to cross reference these requests to an item currently existing on the shelf. If that attempt is unsuccessful the item must be purchased on the open market. Open purchase of hazardous material items must be approved by the base's environmental specialists. Upon initial start up of this system the process took in excess of three weeks. Now, twice-weekly meetings are held with all necessary parties to expeditiously either approve or disapprove of the request. [Ref.2]

All material exiting the HAZMIN Center, as previously mentioned, is affixed with a computer-generated nine-digit bar-code as well as an additional label identifying the material as originating from the Point Mugu Center. The bar-code is unique for each item leaving the HAZMIN Center. The first digit indicates the fiscal year in which the item was issued, the next six digits are a sequential number for issues within that year, and the last two numbers indicates the item number on that particular order request. The bar-code is specifically designed to track the item from issue to return to the Center. The next time that same container is issued it will have a completely different tracking number. [Ref.2]

To minimize disposal costs of expired shelf-life material, Point Mugu has actively sought alternative uses for these goods. While these goods may no longer comply with MILSPEC, they can meet other needs. They have, for example, given materials to Morale, Welfare and Recreation for sports equipment maintenance, paint to local communities to use in painting over graffiti, and local schools for self-help projects. While this action is very positive, to ensure environmental compliance of the HAZMAT the Center has insisted on maintaining cradle-to-grave control of the material until the container is empty or the material has no remaining value. [Ref.2]

E. PUGET SOUND DILEMMA

Fleet and Industrial Supply Center (FISC) Puget Sound, Washington, desires to model their anticipated system after some of the positive results obtained through the Point Mugu system. Puget Sound desires the same type of system but on a much larger scale. They plan to have one HAZMAT Regional Control Center with up to 15 local centers. These Centers will provide all the necessary hazardous materials to the various customers under their immediate jurisdiction on possibly a less than one day basis. The Centers will be connected to the Regional Control Center via a computer network and modem. This will provide all Centers with the capability to immediately identify all hazardous material assets within the region. FISC Puget Sound will control all funding and disbursement of material, and plans to direct the operations of all the Centers. It is anticipated that there will an established transportation system that can easily move material from the Regional Control Center or local center to another local center to meet the customer's demand. [Ref.3]

FISC Puget Sound desires an inventory system that results in zero stockouts and zero disposal. These terms must be defined. "Zero stockouts" is when a customer desires a particular item and it is readily available either at its local (parent) HAZMINCTR or at one of the other centers and is in the customer's possession within 24 hours. "Zero disposal" is defined as when no material will revert from usable material, "A" condition or reuse, to non-usable material simply because its shelf-life has been exceeded and its shelf-life cannot be extended beyond the current assigned date. While the idea of zero stockouts and zero disposals is admirable, it is quite unlikely in a real world scenario. [Ref.3]

F. OVERVIEW OF OPERATIONS

In addition to Point Mugu's Center, we conducted an examination of five other HAZMIN operations and found each to be operating differently. A brief overview of each of the operations is provided.

1. Puget Sound Naval Shipyard

Puget Sound Naval Shipyard operates two separate facilities: the HAZMIN Storage Area and a Reuse store. Neither of these facilities conduct cradle-to-grave management of hazardous material. The Storage Area utilizes the HICS system and is bringing shipyard shops under their control one at a time. They store new material which is ordered by the FISC. The Storage Area's personnel state that the planners and estimators for the shipyard are ordering too much material and must become part of hazardous materials management. The Reuse Store manages only cost avoidance material. Material which is turned into the Reuse Store is accompanied with an accounting document that allows for disposal of the item if it is not demanded within 180 days. The material is made visible to customers via a catalog published every 30 days. Additionally, customers are allowed to browse through the Reuse Store. The Reuse Store does not use the HICS system because there is no "A" condition material. Once the material is "out the door" they do not expect to see it again. [Ref.3]

2. Trident Refit Facility

The Trident Refit Facility Hazmat Center is managed by a Chief Petty Officer and provides hazardous material for the entire facility. It is structured like a toolroom and maintains an inventory of approximately 330 items valued in excess of $45,000 dollars. The facility utilizes the HICS system and has just commenced weighing material in an effort to accurately measure the quantities of both new and used material consumed. They utilize a "homegrown" bar-code and do not utilize the HICS bar-code tracking system. They deliver the estimated daily use of hazardous material to the individual shops in the facility. Additionally, at the end of each work day, Center personnel collect the remaining material. All of the stock held within the storeroom is already bought and paid for by Repair of Other Vessels (ROV) funding. The Chief Petty Officer-in-Charge of the Center sets high and low limits based on his experience. The minimum low limit is two units of an item and the maximum is set no higher than 15 units. [Ref.3]

3. Subase Bangor Reuse Facility

This is strictly a reuse facility. They have a preponderance of small items which they offer to anyone who desires the material. The Facility has barrels of mineral spirits which they distill from paint wastes. The spirits are in demand by auxiliary ships and the paint solids are disposed of as waste. They publish a monthly catalog that is given to users of the Center. Their primary interest is getting rid of material. [Ref.3]

4. Naval Undersea Warfare Center, Keyport, Washington

This material Center appears to have been in place longer than any facility within the Washington state area. The facility utilizes the Environmental Management Information System (EMIS) to manage their hazardous material in a cradle-to-grave fashion. They track all material by a local Material Safety Data Sheet (MSDS) number. The system has been under development for over five years and implementation is approximately 30% completed. The material is received using this system and distributed to the customers. There are about 50 shops and a master supply warehouse at the Keyport facility. Each shop has a shop store that establishes a high and low limit for each of its hazardous materials. Additionally, the base storage facility also manages hazardous material. They maintain an inventory of about 100 items and upon issuance are not reordering for stock in an attempt to minimize hazardous material disposal. They will eventually order all hazardous material only on an as-needed basis. The inventory shop is responsible for maintaining inventories and levels of material, hazardous and non-hazardous, base-wide. This shop reported that the EMIS system is causing a bottleneck in the receipt process since they must record receipt of the item in the supply system and, also record receipt of the item within the EMIS system. [Ref.3]

5. Naval Station Everett, Washington

NAVSTA Everett is a new facility. They are collecting customers' hazardous materials, recording who owns what, and controlling the SERVMART hazardous material. The material is issued to the customers when they need it and more is ordered as necessary. [Ref.3]

G. CONCLUSION

These five facilities and the examination of Point Mugu show that there is no standardization within any hazardous material organization. While some of these organizations are administering a more efficient program than others, none of them are optimizing the problem of minimizing the costs of operation given a desired level of customer service. An inventory model needs to be constructed to meet the goals envisioned by the CHRIMP. This thesis attempts to identify the key variables and develop an inventory management model which can determine the optimal values for both high and low inventory limits given a desired level of customer service.

In the next chapter we examine Point Mugu's HICS database and current existing demand data in an effort to begin modeling an inventory system.

III. DATA ANALYSIS

A. INTRODUCTION

Under the Hazardous Material Minimization Center Concept it is important to accurately forecast the material requirement of each local Center and provide an inventory quantity of material needed while minimizing the potential for waste disposal and minimizing the total cost. In Chapter IV we look at forecasting principles designed to utilize available present information to direct future decisions. In this chapter we focus on the available demand data from the Hazardous Waste Stream Management Facility (HAZMIN Center) at NAWS Point Mugu to determine if it will meet the requirements necessary for accurate forecasting at a regional Center. As mentioned in Chapter II, the HAZMIN Center has been in operation since 1991 and was developed as a hazardous waste minimization facility. This was the best available source of usage data on Cost Avoidance (CA) material.

B. HAZARDOUS INVENTORY CONTROL SYSTEM (HICS)

1. Overview

When the Center first opened there were no existing systems available to provide them with the necessary waste stream management capabilities, so they developed their local system, HICS. It was intended to be an introductory system that could be expanded as a system-wide solution if it proved useful to other users [Ref.2].

Since its introduction, HICS has been adopted by the Office of the Chief of Naval Operations (OK-45) and the Naval Supply Systems Command (SUP-452) as the system for managing hazardous material inventories aboard all naval vessels. It has also been endorsed by Naval Air Systems Command as an easy-to-use program for any command that needs to begin a shore based tracking program.

2. HICS Data Files

HICS utilizes various entry screens to create database files that may be cross referenced from various other screens. We analyzed the HICS database files and the information within the files. We considered the following files important to proper inventory management. The other files in HICS either contained information that was available in the files we analyzed or were local management files that allowed the local facility to customize its operation.

a. AUL.DBF

AUL.DBF is the Authorized Use List database file. This file lists all the items available at the HAZMIN Center and the authorized users. It lists information about each item that might restrict its issue. This file is required to be referenced by HAZMIN Center personnel whenever material is ordered by customers, to restrict the usage of specific materials and to identify material that is no longer needed [Ref.2].

To be added to the Authorized Use list, requesting activities must provide justification that they are required to have the material available and there is no suitable substitute material currently carried. Most common purpose material, such as paints and cleaning compounds, carry no special restrictions. Items used for specific purposes, such as FA-18 engine lube oil or photographic fixing bath, are restricted to those activities trained in its use and specifically performing actions related to the material. A normal entry in this file would only list customer activities authorized to receive the material if there were specific restrictions regarding its use. Items that carry no special restrictions (common use items such as enamel paint, for example), list the Hazardous Waste Stream Facility as the authorized activity.

Discussions with the HAZMAT Center at PT Mugu indicate that their current AUL file has over 400 line items. Only one line item was listed in the data we received for analysis [Ref.2]. This entry was for NSN 6810-00-223-2739, acetone. Acetone is commonly used a solvent and in combination with other chemicals to form different substances not found naturally (hydrogen peroxide, for example). When the REC_CODE entry for this item is cross referenced to the CODES.DBF file (to identify the authorized receiving activities; see below) it lists the Waste Stream Facility as the only authorized user, indicating no restrictions.

b. CAS.DBF

The CAS.DBF file contains Chemical Abstract Service numbers for hazardous material. This file contains a list of chemical constituents and the CAS number associated with each. It also identifies whether a constituent is considered extremely hazardous material or an ozone depleting substance (ODS). It is used with the CHEM.DBF file (see below) to link inventory items at the HAZMIN Center to their constituents.

The file from Point Mugu currently has over 1000 chemical names and CAS numbers. One constituent, sodium phosphate (dibasic), was listed in both the extremely hazardous and ozone depleting categories, and it was the only entry in either column. This chemical is the constituent of acetone. This entry would seem to be in error, since acetone itself is considered to have low acute and chronic toxicity and can be handled safely if common sense precautions are taken [Ref.4:p.186].

c. CHEM.DBF

CHEM.DBF is the main chemical database file. This file links the CAS number from the CAS.DBF to each inventory item. It assists in identifying specific inventory items whose usage is required to be reported under Title III of the Superfund Amendments and Reauthorization Act (SARA) [Ref.5]. Materials that are harmful to the atmosphere when released (such as freon and other ODSs), and materials that are extremely hazardous to humans (such as asbestos or other cancer causing agents), are controlled by government regulations, such as the Clean Air and Clean Water Acts, which severely restrict and even prohibit how and when they may be used.

The file we received from Point Mugu had two entries; one of which is acetone, NSN 6810-00-223-2739. HAZMIN Center personnel indicate that their current data file has over 700 line items. Each inventory item is identified by manufacturer Commercial and Government Entity (CAGE) number and all CAS numbers for each constituent found in that material are listed for each item. Although the primary reason for the file is Title III reporting requirements, different units of issue for the same material can be identified by cross referencing CAGE and CAS numbers. [Ref.2]

d. CODES.DBF

CODES.DBF is the Receiving Code data file. This file contains the Center's current customer file and identifies each activity by an alpha numeric code that may be up to 13 digits. The code is unique to each customer activity and is cross referenced to the Authorized Use List file, the Issue file, and the Returned Container (without labels) file. For certain activities, the file contains customer points of contact and telephone extension numbers. For tenant activities, the code is the activity's primary designator (for example, VXE-6). For base department customers, the code is the internal activity code used by the base for each of its departments and additional codes for branches and divisions within that department. For example, the HAZMIN Center code is P7709. This indicates that it is a division (09) of Aircraft Maintenance Department (P77).

e. DISPAMT.DBF

DISPAMT.DBF is the Disposal Amount (cost) file. This file lists the disposal codes and the amount charged for disposing of a pound of each type of waste. The code is an single digit alpha character from A to Z that provides the Center with an identification of the type of material (for example, corrosive, oxidizer, etc). This file allows the Center to identify high disposal cost material. The file we received from Point Mugu had no entries. Determining these costs is essential for developing an inventory management model.

f. FISC.DBF

FISC.DBF is the Fleet Industrial Supply Center (FISC) ordering information file. This file is generated at the HAZMIN Center and summarizes the ordering information on outgoing orders to the supply system point of entry. The information printed on the DD Form 1348 when an order is produced through the HAZMIN Center is updated in this file as a verification. This file contains the HAZMIN Center name, person placing the order, the date the order was placed and the required delivery date.

g. INVENT.DBF

The INVENT.DBF is the Inventory database file. This file contains most of the management information required to perform inventory management. It contains information on all inventory material, such as stock number, name, on hand quantity, unit of issue, issue price, and location. It also has high and low limit blocks that are, at this time, manually updated by the HAZMIN Center.

The file from Point Mugu had missing or incomplete data blocks. There is, for example, a substitute stock number column that was not used for the data we received. There are also columns to indicate shelf life material and its expiration date. This information is important to determine overall material usage. It provides potential excess and disposal material indicators. [Ref.2].

h. ISSUE.DBF

ISSUE.DBF is the file that contains the issue database. Appendix A contains a sample of the data and a description of each data column. This is one of the most comprehensive file in HICS. As the table shows, this file has the capability of recording total weight of material issued and returned. By standardizing the unit of issue, from gallons, quarts, pints, drums, and containers to pounds and ounces, a more accurate demand pattern forecast can be made to determine the actual material high and low limits. Each issue is referenced to a HICS bar-code number (same as the NSN for the material) which allows the Center to record demand by requesting activity for each item. The data we received had very few weight entries. There were not enough data entries to complete a useful picture of the amount of any given material being reissued and this information is essential to develop accurate demand forecasting. HAZMIN Center personnel acknowledged that this was a problem in previous versions of HICS but that the weight information is now mandatory to process an issue request using HICS Version 4.0, released after the data were compiled. [Ref.2]

i. ORDER.DBF

ORDER.DBF is the order database file. This file records material ordered from the HAZMIN Center. The orders are for both stock replenishment and to fulfill customer requirements for Not-In-Stock (NIS) material. It also documents whether the material ordered was standard stock or open purchase. Appendix A contains a sample of the data and a description of each data column.

The file we received from Point Mugu contained data from March 1993 to July 1994. It was complete, with information recorded in each block for all line entries. This provided lead time information for each type of material that was requested, whether it was Supply System stock, managed by General Services Administration/Defense Logistic Agency (GSA/DLA), or whether it was open purchase. It therefore allowed us to approximate the probability distribution for the lead time required to obtain material from the different sources. This information is presented in the following section on forecasting.

j. POC.DBF

POC.DBF is the Process Operation Code file. This code identifies the use of each item material. It is divided into three separate levels of identification - class (general), subclass (more specific), and name (most specific). This file is cross referenced to the ISSUE.DBF file so that a user may provide specific information on why the material is being requisitioned. This is also useful in crossing to the Authorized Use List file to insure the usage is authorized.

k. RECEIVE.DBF

This file documents the receipt of both "A" condition and CA material that is received into inventory at the HAZMIN Center. For "A" condition material, the quantity received is verified with the amount of material originally ordered. For CA items, the activity that the material was received from is also documented. This provides the Center with the capability to track outstanding containers in the hands of customers.

1. *RTNCON.DBF / RTNCONE.DBF*

Returned Container and Returned Container (without labels) files. These files contained information about the containers issued by the HAZMIN Center and returned. These files cross reference with the HICS bar-code number originally issued with each container by the HICS system and identify material to the original issue when it returns. Containers without labels are either missing the HICS number or were not issued originally by the Center.

C. FORECASTING

This section presents a brief discussion on how we analyzed the original data from Point Mugu in an attempt to forecast future requirements and to develop an initial model.

1. Data Evaluation and Forecasting

The main reason for analyzing the data from Point Mugu was to determine the Economic Order Quantity (EOQ) and the Reorder Point (ROP) for each line item. To find these we first had to determine the probability distributions for the following variables: demand rate for each line item, lead time to fill stock requisitions, amount of returned material, and anticipated quantity of material disposed of as waste.

Data found in the ISSUE.DBF data file provided a demand history of all requisitions filled during our period of interest: from January 1991 to July 1994. See Appendix A, Table A-1. Because of the large amount of data, we found it necessary to reduce it to a more usable form. Separate files were originally received for each fiscal year. To determine overall annual usage of each line item, they were consolidated and sorted by stock number.

Once the data were consolidated, we began the manual process of breaking it down into monthly demand for both "A" condition and CA material. This reduced the total data base from approximately 25,000 entries to 2600 data records, representing "A" condition and CA issues for approximately 1400 line items. This represented both standard stock number and open purchase material.

This information, although useful, was limited to total quantity records for "A" condition items and total unit of issue demands for CA material. Total unit of issue demands refer to the container size listed, not how much material was returned inside the container. For issues of CA material, a generalized approximation for the issue quantity was suggested by the staff at the HAZMIN Center. They assume each issue of CA material to be one half of a "full quantity." [Ref.2]

The 1400 line items were broken down into A, B, and C categories to determine those items that were the most important. Category A items were the top fifteen percent or approximately 200 items that showed a frequency of demand that was equal to or exceeded one demand per quarter during the entire data period. Category B items were the next 35 percent, approximately 450 items, that had more than two demands during the entire data period. Category C were the remaining 720 items (50 percent) which experienced two or less demands during the entire data period. Since it would be extremely difficult to forecast with less data frequency than once per quarter, we focussed our analysis on Category A items.

When we first attempted to analyze these items, we encountered several problems. Although it was easy to separate monthly demand totals, the data was not complete enough to provide an accurate picture of average demand over the entire period. Over 80 percent of the line items experienced less than 1 demand per 90 day period. Those that did experience at least 1 demand per quarter had no steady demand pattern. They would experience consistent demand for a period spanning four to five months and then no demand would be observed for three months. Some items had consistent demand over a 12 month period and then no demand for the remaining period of the data with no discernable pattern that would suggest a specific cause. Another problem we encountered was the unavailability of specific customer demand and stockout data. Although HICS is designed to perform inventory management functions, the current usage of the system and the purpose of the waste stream facility is to minimize waste. The inventory management capabilities at the time we collected the data were being underutilized. [Ref.2]

2. Lead Time Forecasting

As mentioned above, the ORDER.DBF file contains hazardous material requisitions tracked by the HAZMIN Center. See Appendix A, Table A-2. Requisitions to replenish stock use a series of document numbers reserved for the Center; these are H_ series document numbers. Requisitions for DTO material (material that is not in stock at the time of the customer requirement) use customer requisition numbers and use a requisition priority consistent with the customer's Fleet Activity Designator (FAD) and Urgency of Need Designator (UND). These priorities are usually higher than stock replenishment requisitions and are usually filled more quickly by the Supply System. Requisition priorities are recorded in the TRANSACT.DBF file for use in printing out the DD 1348 from the HICS system. Discussions with HAZMAT Center personnel indicate that the proper priority is used in each case [Ref.2].

The ORDER.DBF data file we received from Point Mugu had over 1200 record entries, dated from March 1993 to July 1994. Since there were entries in the ordering and receiving date blocks which were consistent with reasonable time frames for receiving "A" condition material from various supply sources, we were able to determine the distribution of lead times for incoming material. The majority of material ordered was received from the Fleet Industrial Supply Center (FISC) in San Diego (the nearest defense supply depot) within 5 days when the material was ordered as direct turnover (DTO) material, using the requesting activity's requisition.[1] Material ordered for stock by the HAZMIN Center from GSA/DLA (because it was not available from FISC San Diego) took an average of 33 days, with a standard deviation of 22 days. GSA and DLA provide the majority of hazardous material items stocked in the Supply System. There were even fewer open purchase records in our sample that were outstanding longer than five days (only 30 records). The records we analyzed took slightly longer, 38 days, but with less variation (standard deviation of 14 days). Figure 3.1 illustrates these data.

3. Returned Material

The rate of returned material was difficult to capture. Although the Point Mugu HAZMIN Center is one of the only sources of CA material information, the lack of standard recording formats and missing information made it difficult to

[1]Of the 1200 records we reviewed, there were 165 standard stock orders and 30 open purchase records that were outstanding for more than five (5) days. We assumed that requisitions filled within five days were available from either base supply or from FISC San Diego. Only one order using a customer requisition number was outstanding for more than five days. The rest were for stock replenishment.

determine a distribution for such material. As with "A" condition demand, the demand rate for CA material was not complete enough to provide an accurate picture.

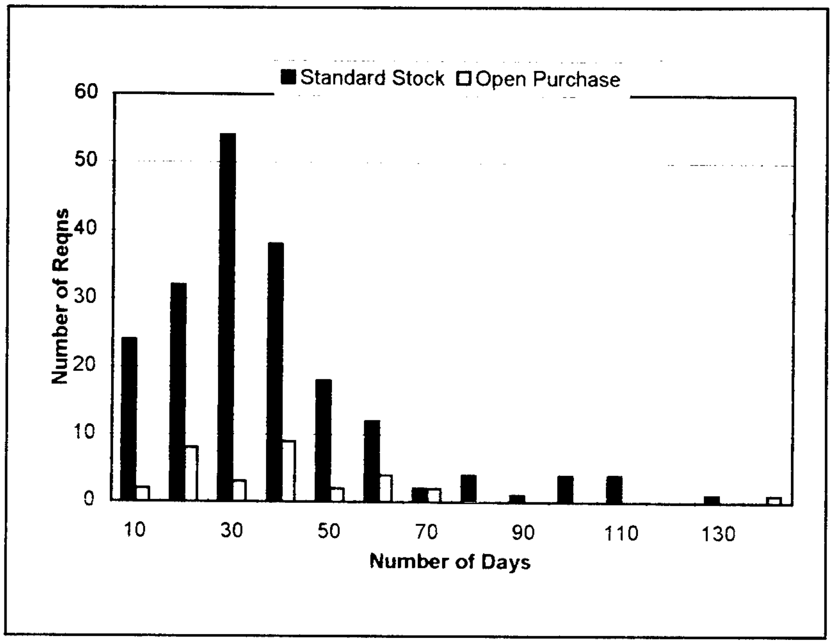

Figure 3.1. Frequency of Lead Time Distributions.

4. Disposals

HICS Version 4.0 has the capability to record information on weights of material sent to disposal. Until this version was released, there was no disposal information tracked by HICS. NAWS Point Mugu has a contract with a commercial vendor that was issued and is monitored by the base Environmental Department. Disposal costs are based on an hourly fee and total pounds of material, not on a commodity cost basis. [Ref.2]

D. CONCLUSION

To develop an accurate forecasting model utilizing historical data it is imperative that the data be accurate and complete and that we be able to identify a genuine probability distribution of demand. The data received from Point Mugu, although very extensive, was not complete enough to provide the necessary information for developing a demand forecasting model. However, the data for lead times was sufficient to provide information on lead time distributions. Obtaining demand data is imperative for forecasting and model development. Thus while we suggest several models in this thesis, they must await the data before the appropriate one can be selected to use for the various facilities in and around FISC Puget Sound.

IV. FORECASTING

A. OVERVIEW

Forecasting of demand and lead time is a fundamental problem that needs to be solved prior to developing any workable inventory model. These forecasts are needed for setting the inventory quantities to provide a given level of customer service and minimizing average annual total variable costs. Forecasting attempts to predict the future based on past results and can be either quantitative or qualitative [Ref.6:p.39]. Quantitative methods include, but are not limited to, moving average, exponential smoothing, and trend projections. These methods utilize historical data and the analyst must assume the behavior pattern will continue over the forecasting time horizon. Quantitative methods are best when used over short time horizons. Qualitative methods include market surveys, the Delphi method, and estimates based on the behavior of similar products. Because of the subjective nature of qualitative forecasting methods, they are better for long-range forecasts [Ref.7:p.112-116]. Within this chapter we examine the information that need to be forecast and the development of a forecasting method.

B. DEMAND RATE AND LEAD TIME FORECASTING

1. Overview

Within the context of this thesis two variables require forecasting: demand rate and lead time. Demand rate is the amount of a particular item customers require over a certain time period. In order to accurately forecast demand rate, a history of demand must be available. As discussed at length in Chapter III, our initial forecasting was going to be accomplished utilizing existing data from Point Mugu. However, as discussed in that chapter, the demand data were insufficient to develop of forecasts. This deficiency in the data led us to explore a less empirical and more theoretical approach for demand forecasting. Lead time is the amount of time required from the time the order is placed until receipt of the order. The lead time data in Point Mugu's database was good enough to make some generic assumptions about lead times and their variances; it was not good enough to produce the detailed analysis of lead time required when attempting to forecast lead time.

The components of the demand rate that we examined for modeling purposes include: demand due to corrective maintenance, demand due to preventive maintenance, demand due to disposal of aged material, and the rate at which unused material is returned from maintenance. The reason for these components is that demand due to preventive maintenance can be considered planned or known demand and demand due to corrective maintenance can be considered unplanned or random demand.

Lead time forecasting is essential when attempting to reach or maintain a customer service level. Lead time can be estimated based on past results or, if no pattern exists, can perhaps be described by a probability distribution. There are three elements of lead time: the lead time from the supplier to the HAZMATCTR, the lead time from the HAZMATCTR to the HAZMINCTR, and the lead time from the HAZMINCTR to the customer. The last two elements of lead time are considered fixed and will be discussed in further detail in the next chapter. All discussions of lead time within this chapter are focused on the lead time from the supplier to the HAZMATCTR.

2. Random Demand

Random demand can be thought of as demand which is unpredictable. We consider it to be demand due entirely to corrective or unplanned maintenance. This demand is the most difficult to forecast because of wide ranges in the amount demanded. Once historical data becomes available for this type of demand a time-series forecasting method can be chosen. In order to apply a time-series method a specified period length must be established over which to measure and forecast the demand rate. The historical demand must be recorded for several periods in the past to provide historical data with which to generate a forecast or to fit the demand pattern to a probability distribution. Our recommendation is to use a time period of one week because current HAZMAT regulations allow a week's worth of HAZMAT to be stored in the work area. The probability distribution most appropriate for low demand items (less than twelve units per time period) would probably be the Poisson distribution and for high demand items (twelve or more units demanded per time period) the Normal distribution would be a good approximation for the Poisson distribution. If period demand is less than twelve units, utilization of the Normal distribution can include a probability of negative demand which is, of course, not possible.

The unit of measurement is another variable that must be standardized for proper forecasting. Demand must be calculated for all items using a common unit of measure. That unit should allow easy determination of the demand for cost avoidance material and it should be possible to convert multiple stock numbered items into a common unit of measurement. The unit of measure recommended is the pound weight. This recommendation is because the HICS systems currently in use have scales available for weighing the material and disposal costs of hazardous waste is measured in pounds.

The importance of converting multiple stock numbered items into a common unit of measure cannot be overstated. All demand of like items (material meeting the same specifications) must be recorded as one item as opposed to recording each stock-numbered version of the item separately. Recording as one item reduces the substitution effect between the various stock-numbered versions of the same item and will allow a reduction in the amount of safety stock carried. This substitution effect may show a false high demand for one stock number while showing a false low demand for a different stock number simply because the Center is out of stock on the false low demand stock number. Recording demand for like items under one stock number would eliminate the substitution effect when one stock number is substituted for another. If the safety stock is recorded separately for the individual stock numbers the total of the separate safety stocks can be expected to exceed the safety stock for the items grouped together as one.

As an example of the safety stock savings expected to be realized, a search of Point Mugu's database revealed eight individual NSN's, as listed in column (1) of Table 4.1, for isopropyl alcohol. Column (2) shows the current unit of issue for these items. Although we do not know the exact size of the bottle and can and the weight of a gallon of isopropyl alcohol, we assume a bottle contains one-eighth of a gallon, a can contains two gallons, and a gallon of isopropyl alcohol weighs eight pounds. Column (3) then represents the unit conversion to pound weight. Suppose that each of these items had a mean and standard deviation of demand as represented in columns (4) and (5), each item is Normally distributed, and the demand for the items are independent of one another. Column (6) then represents the safety stock required of each individual stock number assuming a 95 percent customer service level (standard normal deviate is 1.645). The sum of the safety stocks for these individual stock numbers is 89 pounds while if they were combined the safety stock would only need to be 40 pounds. The standard deviation used to determine the aggregate safety stock is computed by taking the square root of the sum of the squares of the standard deviation for each individual item. This action of aggregating demand into a common unit of measure reduces the overall safety stock and, as a result, would reduce holding costs.

Stock Number	Unit of Issue	Weight Conver -sion	Demand (lbs)	Std Dev	Safety Stock
6505-00-655-8366	Bottle	1	25	5	8.23
6810-00-227-0410	Gallon	8	16	9	14.81
6810-00-286-5435	Gallon	8	40	11	18.10
6810-00-753-4993	Can	16	32	3	4.94
6810-00-855-1158	Gallon	8	24	2	3.29
6810-00-855-6160	Gallon	8	13	4	6.58
6810-00-983-8551	Quart	2	49	18	29.61
6810-01-190-2538	Can	16	12	2	3.29
Total SS					88.83
Aggregate SS				24.16	39.75

Table 4.1. Comparison of Safety Stocks for a Multiple Stock - Numbered Item [Point Mugu Database].

3. Planned Demand

Planned demand is somewhat easier to forecast. For example, a command typically knows when they are going to need material to perform specific planned maintenance tasks. Because of this known requirement they can order the material anytime prior to performing the maintenance action. The customer must establish his planning horizon and that horizon will depend upon known lead time lengths.

The least reliable estimate of lead times are associated with new material ordered for the first time throughout the HAZMATCTR region. However, if the material is a stocked item the lead time would be considerably more reliable and probably also much shorter because the system could already have some of the material on order at any given time. The lead time and thus the planning horizon would diminish for each day that the material order had been placed prior to the customer requirement.

With proper planning a customer should be able to order the material well enough in advance to assure that it will be on hand just as it is needed. This requires knowledge of the lead time required to receive material after an order has been placed by the HAZMATCTR.

Unfortunately, as we will demonstrate in the following chapters, that lead time can be highly variable. This variability requires careful planning on the part of the customer because if they want to ensure that the material will be available when required they must estimate the maximum value that the lead time can take. Since lead time is random, a specific probability distribution needs to be assumed. If that distribution does not have a finite right tail then some level of service must be considered. The customer usually has some desired level of service. For example if a Normal distribution for lead time is assumed, and a customer desires a service level of 99% (or 99 times out of 100 the material is available when needed), the planning horizon must include the average lead time plus 2.33 times the standard deviation of lead time. Thus, if the average lead time for an item is 30 days and the standard deviation of the lead time for that item is 20 days, the customer's planning horizon should be 30 days plus 2.33 times 20 days, or a total of 77 days. This means they must know 77 days in advance of any requirement so that they can place an order which they desire to arrive on time for 99% of the orders they place for that item.

4. A Mixture of Random and Planned Demand

The planned requirement portion is ideal in a world where requirements never become emergent. An emergent requirement is a requirement for goods that cannot be anticipated. An example of this type of requirement would be when equipment suffers a breakdown for the first time. A mixture of both random and planned demand is typical in most situations simply because not all of the customers can plan for emerging requirements or the customers are poor planners. Upon startup, the percentage of overall random demand can therefore be expected to be higher than when the HAZMATCTR operation has been in operation for several years. As the operation continues the planned component of demand should increase because of experience gained by customers in planning for their HAZMAT requirements.

5. Returned Material

Excess material returned after completion of a maintenance action can be forecast in the same manner as random demand. Remembering that the material is issued to a customer and the customer is allowed to maintain the material for one week, the returned material "demand" will lag initial demand by up to one week. The amount of this material should decrease as the customer's planning improves.

6. Material Disposal

The amount of material sent for disposal as hazardous waste can be forecast in the same manner as random demand because the material will be on the shelf when shelf-life expiration takes place. The amount of material disposed of is expected to decrease over the life of the HAZMATCTR.

C. DETERMINATION OF DEMAND OR LEAD TIME DISTRIBUTIONS

When dealing with a random demand rate and a random lead time an attempt must be made to fit the data to probability distributions. Data must first be collected. In the case of demand for a HAZMAT item, the data would be the weekly demand for the item in pound weight. For the lead time, the data would be the time it takes to receive an order once it is placed. Observations are needed over a period of time representative of the conditions expected in the future. The more data recorded, the better the model will represent reality.

Having obtained sufficient data, the data can be separated into ten to fifteen groups of equal length over the entire spectrum of the data. The number of occurrences within each of the groups can be recorded and a histogram plotted. The frequency information can also be analyzed using any of the commercially-developed software programs that will fit data to a known probability distribution, usually through a goodness-of-fit test. If the data for either demand or lead time does not fit any known distribution an empirical distribution can be developed using the actual data. This would certainly be appropriate if the data are scarce. Finally, if demand and lead time are random, a convolution of the two distributions can be made to provide the probability distribution for demand during lead time [Ref.6:p.239].

D. FORECASTING TECHNIQUES

After sufficient demand history is obtained, forecasting of the distribution parameters (namely, mean and standard deviation) can also begin. Several different types of forecasting techniques can be used. The two most common are Moving Average and Exponential Smoothing. It is anticipated that the demand rate will ramp upwards upon implementation until all HAZMINCTR's and commands within the Puget Sound area become partners in the program. After that the mean demand rate can be expected to remain fairly constant but the standard deviation should decrease as more of the demand is shifted from random to planned demand and planning estimates become more accurate. The demand rate would approach a constant mean demand rate as the system reaches steady state operations in an ideal world. The reality of this is as new constraints are imposed that affect HAZMAT the demand rate will adjust accordingly.

1. Moving Average

The moving average simply averages the demand observed for each of a specified number of previous periods to attempt to predict the next period's demand. Moving averages based on between two and six periods are recommended because the larger the number of periods the less sensitive the averages are to random fluctuations in the observed data [Ref.8:p.130]. The formula for computing a moving average for the demand rate is:

$$\bar{d}_{n+1} = \frac{\sum_{i=1}^{n} d_i}{n}; \qquad (4.1)$$

where d_1 = Oldest demand rate observation;

d_n = Newest demand rate observation;

$\bar{d}_{n+1}$ = Forecasted demand rate; and

n = Number of demand rate observations averaged together.

2. Exponential Smoothing

Exponential smoothing is a forecasting technique that has been used extensively by the U. S. Navy to predict future demand. It involves choosing an alpha value that weight the most recent period. This value is between 0.00 and 1.00. The general formula for exponential smoothing is:

$$\bar{d}_{n+1} = \alpha d_n + (1-\alpha)\,\bar{d}_n \tag{4.2}$$

where $\bar{d}_{n+1}$ = Forecast for period n + 1;

$\bar{d}_n$ = Forecast for period n;

d_n = Actual demand during period n; and

α = Smoothing factor.

3. Trending and Seasonality

Trending and seasonality of the demand data must also be considered. Trending should be examined for any exponential smoothing forecast, but a year's worth of data should be available. Additionally, seasonality should also be examined when utilizing exponential smoothing, but at least two years' worth of data should be available.

4. Lead Time Forecasting

Forecasting lead time is different than forecasting demand. In forecasting demand you are estimating how much of a given item will be required during a given time period. In forecasting lead time the forecaster is trying to determine how long each order takes from ordering to delivery. The UICP inventory model for forecasting lead time uses a combination of an average and exponential smoothing. Initially, they compute a quarterly average of lead times of all orders for like items then exponentially smooth this figure. The Aviation Supply Office (ASO) utilizes a constant alpha value of 0.5. The Ships Parts Control Center (SPCC) utilizes an alpha value of 0.2, 0.5, or 1.0, depending upon the length of time since the last lead time measurement. [Ref.9:p.3-A-33,34]

5. Demand Rate Forecasting Method Evaluation

Forecasts can be made using both the moving average and exponential smoothing models and their results compared to decide which is the best. This is done by determining the errors resulting from each forecasting method. There are several different measures which can be used to compare forecasting methods [Ref.6:p.42]. Two commonly used measures for evaluating a forecasting method are Mean Squared Error (MSE) and Mean Absolute Deviation (MAD) [Ref.6:p.42]. The MSE weights errors in proportion to their squared values, weighing larger errors more heavily than smaller errors. The MAD weights all errors the same regardless of the magnitude of the errors. [Ref.6:p.42-43] The preferred measure is MAD because the concern is not that the forecast follow fluctuations closely, but that the mean is being tracked closely.

The direction of forecast errors can also be measured using the Mean Error (ME)(also known as the Arithmetic Sum of Errors). This is measured by the actual demand for a given period and subtracting the forecasted demand for the same period. Completing this computation for a number of periods shows the tendency to over or under forecast. A negative figure for the ME shows a tendency to overforecast and a positive figure shows a tendency to underforecast. [Ref.6:p.43]

When comparing demand rate forecasting techniques the time interval for the evaluation must be the same for the two different methods. In other words, the sum of the errors for each method must be made over the same time periods. The best forecasting method will be the one with the lowest error over the evaluation period. Probably the most practical length of evaluation is fifty-two periods for weekly data. It is suggested that for the first two years of operation the moving average will probably result in the best demand rate forecasts and as steady-state operations are approached a shift to exponential smoothing will probably be in order. This is a result of the expected trends after the system becomes operational. It is expected that the planned demand rate would rise and the random, cost avoidance and disposal demand rates would decrease over several years until steady-state conditions are approached. The two-months moving average might provide the best forecasting method for following these downward trends until they damp out.

E. CHOOSING THE BEST OVERALL FORECASTING TECHNIQUE FOR THE HAZMIN CENTER CONCEPT

While both the moving average and exponential smoothing techniques may seem relatively straight forward and simple when dealing with the demand rate for a single line item, complexity is added, due to volume, when dealing with a database that approaches or exceeds 1000 items. Rather than dealing with different forecasting methods for different items it would probably be best to choose a forecasting method that fits low demand and a forecasting method that fits high demand items, with all items falling into one of these two categories. The cutoff for low or high demand items is probably best where the Normal distribution becomes a good approximation for the Poisson distribution, or at twelve pounds per time period.

Once the system reaches a steady-state environment the best method for forecasting demand for the very active or high demand items at that point in time will probably be an exponential smoothing model with alpha equal to 0.1. This suggestion is based on a study using simulated demand assuming the underlying distribution was Poisson or Normal and the test interval was 72 periods with a six period warmup. Table 4.2 shows the results of this comparison of distributions and forecasting methods. The distribution column of Table 4.2 lists the distribution and in parenthesis the mean and standard deviation of hypothetical demand data. For the Poisson distribution the mean and standard deviation are equal. The measure of effectiveness was the MSE and no measure of over or underforecasting was computed. The forecasting methods evaluated were two to six month moving averages and exponential smoothing with optimal alpha values. When utilizing the Normal distribution all negative numbers generated by the simulation given a certain mean and standard deviation were set equal to zero because negative demand is not meaningful.

The purpose of this exercise of determining the best forecasting method is to illustrate the process. The mean demand rates are known, and the low alpha values illustrate the fact that the best forecast is the mean we used to create the data. In the real world we do not know the mean or how demand data will be distributed.

After identifying the forecasting model most likely to be the best, this simulation was further embellished assuming an alpha = 0.10 exponential smoothing model (an approximate average of the above results). The above distributions were re-evaluated, assuming only a 0.1 exponential smoothing forecast, and reevaluated against the moving average forecast model. The results remained the same in all cases with the exception of a Poisson distribution (mean = 5.0) where a six-month moving average was best and the Normal distribution (mean = 1.0, standard deviation = 1.0) where the three-month moving average became the best forecasting technique.

Distribution	**Alpha Value**	**Forecasting Method**
Poisson (0.1)	0.01	Exponential Smoothing
Poisson (0.5)	0.01	Exponential Smoothing
Poisson (1.0)	0.10	Exponential Smoothing
Poisson (2.0)	0.08	Exponential Smoothing
Poisson (5.0)	0.20	Exponential Smoothing
Poisson (20.0)	0.09	Exponential Smoothing
Poisson (50.0)	0.08	Exponential Smoothing
Normal (1,1)	0.13	Exponential Smoothing
Normal (10,3.16)	0.20	Exponential Smoothing
Normal (10,10)	0.13	Exponential Smoothing
Normal (100,10)	0.05	Exponential Smoothing

Table 4.2. Results of Comparing Forecasting Models for Simulated Demands Assuming the Poisson and Normal Distributions.

Reaching a steady-state condition will probably be a lengthy process as well. All commands must be on line with the regional concept and should have gone through at least one complete maintenance cycle. The process will probably take in excess of 36 months or more because of the preventive maintenance structure of the United States Navy. We suggest a start-up forecasting model of a two month moving average which will allow the forecast to easily follow any demand trends. When the mean demand rate approaches some steady value it is recommended that the forecasting method be shifted to an alpha = 0.10 exponential smoothing model which should provide the best results as demonstrated in Table 4.2.

After evaluating the most common forecasting methods and achieving an adequate basis for making forecasting decisions, in the following chapter we discuss the costs associated with the HAZMATCTR concept.

V. COST AND CONSTRAINT FACTOR ANALYSIS

A. INTRODUCTION

The objective of any inventory model is to have material in the right amounts in the right place, at the right time, at a low cost. Most of the costs associated with regional hazardous inventory management operations are the same as those of any inventory management system. For each item, these costs are normally considered to be the unit purchase cost, the ordering cost, the holding cost, the shortage or backorder cost, and the transportation cost. However, due to the nature of HAZMAT ordering, storing, handling, packaging, and transporting, there may be additional costs that affect the order quantity and reorder point for any given item. Special handling procedures and facility requirements introduce cost considerations not normally associated with non-hazardous items. Additionally, the cost of disposing of the used or obsolete material as waste is not found in the basic inventory models.

Certain costs can be determined in a straight forward manner. Others require consideration of additional factors and, as a result, can be complicated to quantify. Tersine [Ref.6:p.113-115] and Ballou [Ref.7:p.413-416] describe how to determine the basic costs. We will review these and, in addition, attempt to identify and suggest ways to determine the additional costs relevant to our model in the following sections.

B. UNIT COST

The unit cost is the cost to obtain the item from the supply source. This is either the government price (for GSA/DLA material) or the purchase order price for non-standard items (purchase order price includes freight charges to the ordering activity). We assume the cost to be constant for each line item; that is, (1) any quantity discounts are applied to each unit rather than incrementally; and (2) the method of procurement is the same for all units of a particular line item (an item is either standard stock or open purchase, not both). This latter assumption standardizes the unit cost by discounting the situation when standard stock items are purchased locally at a different price than the stock system price.

Local purchase of HAZMAT is an issue that must be addressed. NAVSUPINST 4200.85A [Ref.10] sets down specific guidance as to what requirements must be met to procure material from other than DOD sources. The applicable pages from this instruction are included as Appendix B. Material is generally not authorized for local procurement unless approval is obtained from a designated Navy Hazardous Material minimization office. Approval is generally not given if stock numbered material is available. Exceptions may be the criticality of the requirement, the non-availability of system assets, or other emergent situations. The current alternative is the Prime Vendor concept, where specific vendors identified by each item manager may provide the material direct to the requesting activity. These procedures usually result in a faster delivery time. This concept is not currently in place at FISC Puget Sound.

With the need to minimize the order cycle of HAZMAT, to minimize costs, and avoid excess stock levels, it may be necessary to investigate the Prime Vendor concept. However, until this occurs, we made an additional assumption that no material would be procured locally using other than small purchase procedures (less than $25,000 per purchase request). Requirements in excess of this amount are expected to be acquired from the supply system, either from GSA or DLA.

C. ORDER COST

1. Background

Ordering cost is the expense associated with the determination of requirements, processing of a purchase request, and subsequent actions through receipt of the order [Ref.11:Encl.(1),part V]. This cost is considered to be a fixed dollar value for all orders. The annual total costs to order will be the product of this cost and the total number of orders placed each year for a given item.

The ordering cost includes the cost of comparing the different suppliers, preparing the requisition or purchase order, receiving the materials and inspecting them, following up on any outstanding orders (whether they are experiencing unusual delay or have dropped out of the system altogether), and doing the processing required to complete the transaction (annotating the invoice with payment information, updating the outstanding order file and the receipt file, properly filing the paperwork for future audit, etc.).

DODI 4140.39 [Ref.11] contains a complete list of functional elements DOD includes in the cost to order at the ICP level. The ordering cost will vary depending on the type of procurement. Standard stock orders require much less time and labor than open purchase. Small purchase buys (less than $25,000) utilizing prime vendors or made against local Blanket Purchase Agreements (BPAs) require less time and labor than other types of purchases.

2. Study of Ordering Costs at DLA ICPs

We utilized a study commissioned by DLA with an outside consulting firm, SYNERGY, Inc [Ref.12]. As background, when DLA first implemented their EOQ model within its Standard Automated Material Management System (SAMMS), they elected to use a single T value (square root of the ratio of the cost-to-order and the cost-to-hold) for all items within a commodity (the value of T was assumed to be constant), rather than use a multiple cost model. The purpose of the SYNERGY study was develop a means to determine those multiple costs and determine the impact of using a multiple cost model.

As part of their analysis, SYNERGY identified the ordering cost of material for each DLA ICP. This analysis was extensive and included average performance time and labor cost for each functional element in the cost-to-order value. To help isolate the specific order method for a given item, DLA computes a dollar value of quarterly demand and, based on this amount, the computer assigns each item to procurement under an appropriate SAMMS Automated Small Purchase System (SASP). Table 5.1 summarizes the relevant ordering costs [Ref.12:p.6].

Activity	Standard Stock/ BPA calls	non-BPA orders
Defense Construction Supply Center (DCSC)	$ 51	$102
Defense Electronics Supply Center (DESC)	$ 52	$102
Defense General Supply Center (DGSC)	$ 45	$ 95
Defense Industrial Supply Center (DISC)	$ 61	$106
Defense Personnel Support Center - (DPSC-M) medical	n/a	$105
Defense Personnel Support Center - (DPSC-CT) clothing and textiles	n/a	$285

Table 5.1. DLA Ordering Costs by Inventory Control Point.

The table shows the ordering cost for each ICP of the two major types of procurement we are assuming for the HAZMATCTR: standard stock and non-standard, small purchase (less than $25,000) procurement. DLA does not use SASP I for medical or clothing and textile items so those cost were not available. We are assuming that standard stock buys (including buys from prime vendors) and purchases against a BPA made by the HAZMATCTR are very similar to DLA ICP purchases of small Dollar-Value-of-Quarterly-Demand (DVQD) items. These types of procurement fall under the ICP SASP I program, which uses a single source, eligible vendor from which to make BPA and indefinite delivery-type contract (IDTC) buys. Since the HAZMATCTR is constrained to single source for stock buys (the Supply System) and performs BPA buys essentially the same as the ICP, we are assuming the cost figures determined by the SYNERGY study for stock/BPA buy situations adequately represent the circumstances at FISC Puget Sound. Under the same assumption, non-standard, non-BPA buys at FISC Puget Sound were assumed to be very similar to the DLA ICP Small/Manual purchase procedures. These procedures at the ICP level follow the same dollar values ($0.01 to $25,000.00) the HAZMATCTR must use and assume that the procurement is processed manually. As Table 5.1 illustrates, there is a significant increase in cost-to-order with a manual process.

3. Setting the Value

Using the cost to order figures discussed above, we then attempted to identify the HAZMAT order pattern for a typical DOD HAZMAT ordering activity. We used a sample of 500 Navy stock numbers from the inventory database at Point Mugu. We identified the item manager for each stock number and found that the majority of non-petroleum HAZMAT is managed by either GSA, DGSC, or DISC. The percentages of items managed by these activities for the sample we utilized were 33.4%, 45.2%, and 21.4%, respectively. Although we did not have a relative cost-to-order for GSA, we assumed that the cost to order would be similar to the cost at DISC.[2] We weighted the cost

[2]HAZMAT managed by GSA and DISC is limited to some paints, sealers, and adhesives, Federal Supply Group 80. HAZMAT managed by DGSC includes chemicals and chemical products, photographic

figures in Table 5.1 using the percentages (we combined DISC and GSA) and estimated a cost-to-order of $54 per order for stock/BPA buys and $101 per order for open purchase/non-BPA procurement. We assumed for our analysis that all orders are for standard supply system stock or small purchase BPA buys so our calculations of ordering costs is $54. This figure seemed justified in light of a recent program implemented at DLA. As part of the Defense Performance Review to reinvent the way DOD does business, a six-month program is being tested at six Navy sites in CONUS whereby customers who find a lower total cost on the commercial market for any material centrally managed by DLA can ask DLA to provide the material at that lower cost. The "total cost" is the local purchase cost plus an additional $50 representing the administrative cost of ordering [Ref.13]. Since this represented an average cost for all DLA material, we decided that the $54 figure would reasonably account for any additional cost of ordering hazardous material.

D. HOLDING COSTS

1. Basic Holding Costs

The holding cost for an item is the cost of investing in the item and maintaining it in the physical inventory. This includes the cost of capital invested in the inventory, the cost of storage (including the cost of storage facility maintenance), the cost of losses that occur while the material is being stored, and the cost of material that is no longer of value to the customer whether as a result of obsolescence or shelf life expiration.

Government holding costs for typical non-hazardous, non-repairable material have assumed a relationship between the unit cost of an item and the cost of holding it for a period

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supplies, solid fuels, and oils and greases.[Ref.14:para 21148] of time. It is expressed as the cost per year per dollar of average on-hand inventory. The current annual holding cost rates for consumable items at DLA activities are provided in Table 5.2 [Ref.12:p.151].

Activity	Investment Cost	Storage Cost	Obsolescence Cost	Other Losses	Holding Rate
DCSC	10%	1%	6%	0%	17%
DESC	10	1	8	0	19
DGSC	10	1	6	0	17
DISC	10	1	7	0	18
DPSC-M	10	1	1	0	12
DPSC-CT	10	1	7	0	18

Table 5.2. DLA Holding Costs by Inventory Control Point.

The 7 percent obsolescence cost at DISC and DPSC-CT are assumed since neither of these activities specifically apply a number to this component. These numbers were provided by DLA-OS to allow SYNERGY to make comparisons [Ref.12:p.149].

2. Hazardous Material Holding Costs

HAZMAT has certain unique characteristics that may change these cost percentages. Several of the above listed components may change significantly when the item being held is hazardous in nature.

a. Cost of Storage

Storage facilities for HAZMAT must meet certain standards. DOD Instruction 4145.19R, "Storage and Materials Handling", Chapter 5, [Ref.15] provides additional conditions that must be met at facilities that store hazardous materials. These requirements include additional fire suppression capabilities (such as extra fire extinguishers and fire proof doors), additional safety devices (eye wash stations, spark-proof light fixtures and light switches), and additional space restrictions between materials (to improve emergency access and to minimize risk of mixing incompatible materials and causing potentially dangerous chemical reactions). Hence, the cost of storage for hazardous materials may be more than the 1 percent projected by DLA at each of its activities. How much more is not known for certain, but we attempt to set a specific value below.

b. Cost of Obsolescence

This cost is intended to include losses of material due to all causes that render the on-hand material superfluous [Ref.11:Encl.4,part IIB]. Although most general purpose stock items have deteriorative qualities (10 years is considered the useful life of non-shelf life items), obsolescence is more of an issue for hazardous items, where nearly 70 percent are shelf life coded. Shelf life coded "A" condition and CA material both require inspection for obsolescence (remaining shelf life) . Material must be disposed of for which the shelf life was either never extendable (Type I) or the shelf life has reached its maximum allowable extended life (Type II). Although the actual cost to dispose of the material will be discussed in the following section, the increased management attention and manpower requirements to identify expired shelf life material should be added to the holding cost of HAZMAT.

c. Setting the Value

With the information from Table 5.2 and the factors discussed above, we made several assumptions. First, that cost of storage, although not a large percentage, was more than the 1% currently projected by DLA. We assumed a figure of 2%. Also, given the increased significance of identifying obsolescence, we assumed that an additional 1 or 2 percent on top of the existing DGSC and DISC cost of obsolescence figures was also not unreasonable. For our model, we therefore assumed the following holding cost components:

Cost of capital	10%
Cost of storage facilities	2%
Other Losses	0%
Obsolescence	8%
Total	20%

E. DISPOSAL COSTS

1. Background

Disposal costs are the costs of removing, repackaging, and transporting material that no longer fulfills its intended purpose to the Hazardous Waste Collection area. We discussed identification of obsolescent material requiring disposal as a factor of holding costs. The actual direct costs represent a separate cost factor. This additional factor is the total cost of "A" condition and CA material (returned by the customer in a reusable condition) that must be disposed of as "waste" by the HAZMINCTR. Disposal costs of "A" condition material are a function of the quantity of material ordered while disposal costs of reuse material are a function of the quantity of material returned.

2. Setting the Value

Appendix C is the existing contract for hazardous waste disposal at FISC Puget Sound. The total annual disposal cost can be found by cross referencing each item on the AUL with its appropriate item disposal cost from Appendix C and multiplying by the amount of material disposed.

Personnel at the FISC Reuse Store currently estimate that no more than 2% of the returned material of any particular item is disposed of as waste. There is no current estimate of how much "A" condition material reaches its maximum shelf life and must be disposed. However, because average reuse material would presumably have less remaining shelf life than average "A" condition and may suffer reduction of usefulness (slight contamination, evaporation of VOC after the container is opened, etc.), we are estimating that annual disposal costs will equal the cost of disposal times 2% of the returned material. We are assuming that "A" condition material is received with the majority of its shelf life remaining and that no disposals of "A" condition material are made.

F. SHORTAGE COSTS AND LEVEL OF SERVICE

1. Parameter Definitions for the Shortage Costs

The following parameters are used. Quantities are in pound.

R = Annual Demand,

Y = Annual Returned Quantity,

C_P = Unit purchase cost of the item,

I = Annual holding cost rate,

D_{LT} = Mean demand during lead time - Total,

ROP = Reorder Point, and

λ = Shortage cost per unit.

2. Background

Shortage costs are the costs resulting from not being able to provide an item when it is requested by a customer. This may be seen as the cost associated with a loss of readiness or the added expense of expediting requisitions. It can also be found in the customer's lack of confidence in the ability of the system to support their requirements. This may force customers to circumvent normal procurement procedures and procure material from local vendors without purchase authority.[3] Quantifying these types of stockout costs is a difficult issue.

It should be understood that prior to reaching the reorder point the risk of stockout is zero and 100 percent of all customer orders will be filled. Stockouts occur after ordering additional material and before it arrives.

Tersine [Ref.6:p.209] points out that there are two schools of thought on how to establish safety stocks to minimize stockouts. The first addresses known stockout costs (such as the additional expediting cost) while the second deals with unknown costs (such as loss of customer goodwill).

We use the second approach. Management establishes a level of service policy to react to customer requirements. This level of service assumes a tradeoff between being able to satisfy 100 percent of customer demands (right amount, right time, right place, and right condition) based on some known or assumed probability distribution of demand during lead time, and the cost of providing that level of service. Tersine shows that there is an optimum level of customer service determined by taking the first derivative of the expected

[3]Only authorized DOD contracting officers with a valid contracting warrant have the authority to obligate DOD funds through commercial contracts with local vendors. Without this authority such actions are considered to be unauthorized commitments [Ref. 4].

safety stock cost equation with respect to the reorder point and setting the resulting equation equal to zero. Tersine's expected annual total safety stock cost (TC) equation, when stockouts are on a per unit basis, is the amount of safety stock (in units) multiplied by the unit holding cost plus the shortage cost per unit multiplied by the number of order cycles per year (annual demand divided by the order quantity) multiplied by the number of units demanded during lead time that can be expected to exceed the reorder point. This is written as follows [Ref.6:p.216]:

$$TC = IC_P SS + \lambda \frac{R}{Q} [E(D_{LT} > ROP)] \ . \tag{5.1}$$

The first derivative of **TC** with respect to the Reorder Point gives the RISK OF STOCKOUT equation:

$$RISK\ OF\ STOCKOUT = \frac{IC_P Q}{\lambda R} \ . \tag{5.2}$$

Solving this "RISK" equation for λ, we get

$$\lambda = \frac{IC_P Q}{R(RISK)} \ ; \tag{5.3}$$

which we can use to compute an implied value for the shortage cost for a desired service level which we define as 1 - RISK. We will need to use the formula for Q to be derived in the next chapter (equation (6.23)) to complete the derivation of the formula for the implied value of λ as a function of RISK.

3. Setting the Value

For safety stock calculations we assume a level of service of 99%, or 2.33 standard deviations from the mean, is appropriate for the Hazardous Material Minimization Center Concept model.

G. TRANSPORTATION COSTS

1. Introduction

One of the more important considerations of an inventory model for managing HAZMAT are the cost factors attributable to the movement of material. It is anticipated that there will be two different transportation systems for moving the material: a regional network from the HAZMATCTR (the receiving warehouse at FISC Puget Sound) to the HAZMINCTRs and local networks linking each HAZMINCTRs to their end users. We will try to determine what effect, if any, transportation decisions will have on selecting the most cost effective method for ordering hazardous material.

2. Overview of the Proposed Transportation System

The Regional Hazardous Material Management Facility, Puget Sound, will be the inventory management activity responsible for ordering, receiving, and maintaining inventory control of HAZMAT at the HAZMINCTRs within its geographic area of influence. There will be a computer network linking the HAZMATCTR to all HAZMINCTRs and each Center to the other sites. This network will provide real time inventory management information at each HAZMINCTR. It will also provide direct on-line communications capabilities that will enhance the inventory management functions between the HAZMATCTR and the various HAZMINCTRs.

The HAZMATCTR will track issues, set high and low limits for the HAZMINCTRs, and order material from the supply system and through open purchase to meet the desired customer service level discussed in Section F. The HAZMATCTR will also manage the hazardous waste disposal for the region. Hence, it has the responsibility of providing an effective transportation network to accomplish these tasks.

Figure 5.1 is a map of the local geographic area and the relative locations of the HAZMATCTR and the current proposed HAZMINCTR sites, showing the major roads and the most likely ferries to be used. There are two separate transportation networks to be considered but we are primarily concerned with the regional network, from the HAZMATCTR to the HAZMINCTRs.

3. HAZMATCTR To HAZMINCTR Regional Delivery Network

a. Overview

This network is expected to operate between a central depot (HAZMATCTR) and its customers (HAZMINCTRs). Material, ordered by the HAZMATCTR to replace or augment HAZMINCTR stock, will be received (and briefly stored) at the HAZMATCTR and placed on a truck to be delivered to the various HAZMINCTRs on a regularly scheduled basis. It is anticipated that scheduled deliveries will either be daily or weekly, but no less frequently than weekly. Material will be loaded until truck capacity is reached. If more than a truckload of material is available for delivery to the HAZMINCTRs during the normal delivery cycle, the HAZMATCTR should assign a priority to each order, with Direct Turnover (DTO) and material showing low or zero balance stock levels at the HAZMINCTRs given the highest priority and "top off" items given the lowest priority. Material not loaded due to truck capacity constraints will have to wait for the next scheduled cycle. The driver will also be responsible for the pickup and delivery of HAZMAT from one HAZMINCTR to another and the pickup of hazardous waste accumulated at the HAZMINCTRs and its delivery to the designated waste processing area.

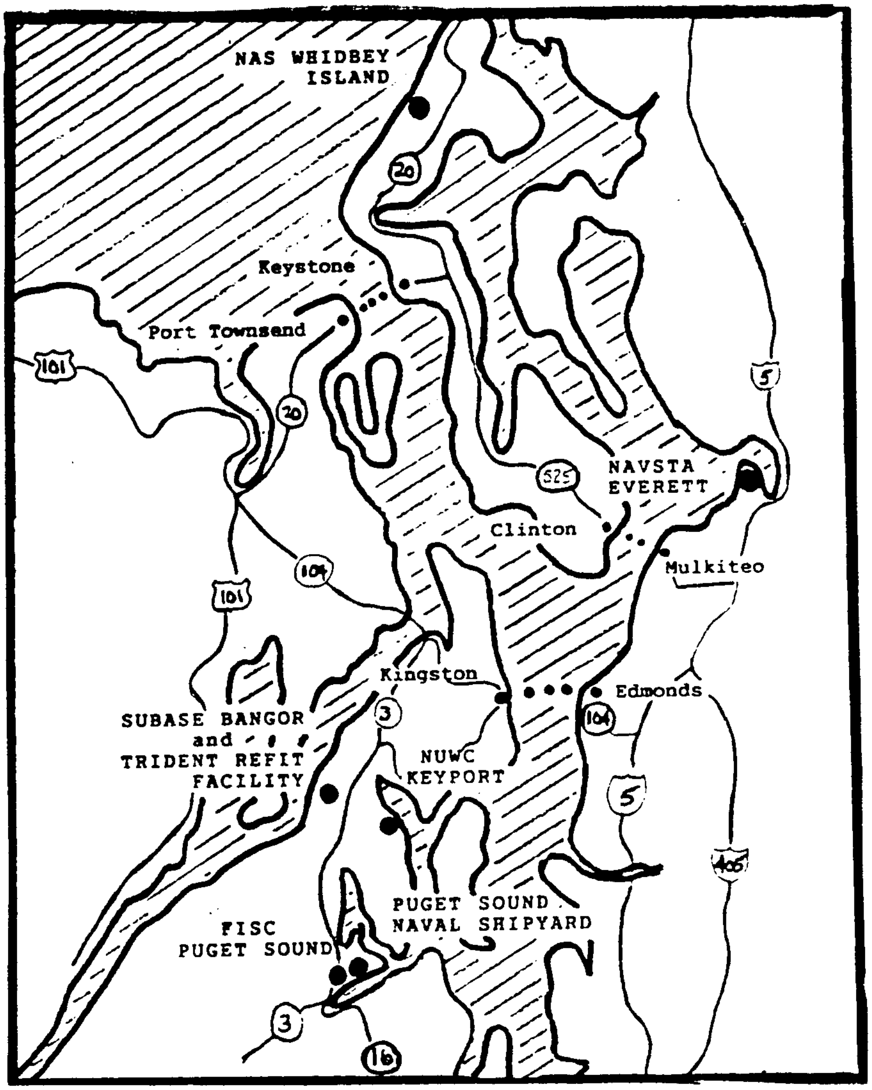

Figure 5.1. Map of the Puget Sound area.

b. Delivery and Pickup Routes

The choice of the delivery and pickup routes can best be described as the "Traveling Salesman Problem," where a shortest route is desired that reaches each intermediate point and returns to the point of origin. There are several options in choosing the specific pickup and delivery route to be used, whether the measure of performance is time, distance, or cost. We used time as the measure since it includes cost aspects and because the time to travel a given distance in the Puget Sound area is affected by the geography of the area; i.e., short distances across water may take a long time to traverse.

(1) Combine deliveries with pickups. This method would combine the delivery of HAZMAT to each HAZMINCTR on the delivery route with the pickup of accumulated HAZWASTE for all sites on a single route. The extent to which this is feasible will depend on the vehicle capacities, the volume of material involved, and the degree to which pickups at prior stops block access to material on the vehicle at subsequent stops. It is also necessary for the driver of the vehicle to comply with all regulations regarding the segregation of the various categories of HAZMAT and HAZWASTE [Ref.16]. The route should be a loop and be designed to pass each HAZMINCTR only once during a cycle.

(2) Separate deliveries and pickups. This option would have the vehicle make two stops at each HAZMINCTR, making deliveries on the outbound trip, pickups on the return leg, using a single route for all sites. It would start its delivery cycle from the HAZMATCTR and proceed in order to each HAZMINCTR. After the final delivery of HAZMAT to the most distance site, it would retrace the original route and pickup any accumulated HAZWASTE. Thus multiple routes would be needed.

(3) Multiple routes. It may not be feasible, either due to quantity of material to be transported or the time and distance necessary to reach the outlying sites (i.e., Naval Station, Everett (NAVSTA) and Naval Air Station, Whidbey Island (NASWI)) to have only one route responsible for all the

sites. More than one route seems inevitable. The routes could either be loops or separate delivery/pickup legs.

c. *Type of Vehicle to be Used*

The type of vehicle(s) available may impact on the design of each route. Not only is maximum route capacity affected, but the time it takes to complete one delivery/pickup cycle is affected by load and unload time. A side-loading stake truck is easier to load by forklift than a van but is usually more susceptible to weather considerations. A pickup truck is easy to load but has a smaller maximum capacity. The current situation at FISC Puget Sound is described below.

d. *Schedule of Deliveries*

It is necessary to determine a schedule that the vehicles will follow. Two questions must still be addressed: First, how often will scheduled deliveries and pickups occur? Second, will all deliveries be made on the same scheduled day or will different HAZMINCTRS receive service on different days of the week?

The answers to these questions may be found in the quantity of material delivered during a normal cycle and the capacity of the vehicle to be used. For example, FISC Puget Sound currently has one 5-ton covered van available for HAZMAT material deliveries to the various HAZMINCTRs. There is no data available on how much HAZMAT is currently delivered to the various sites. Since we are assuming that the capacity of the vehicle ultimately chosen by the HAZMATCTR will at least be sufficient to carry one week's requirements, it is recommended that the vehicle make weekly deliveries and that the vehicle make stops at each location along its route on the same day each week, along the routes proposed below. A third consideration, whether any of the HAZMINCTRs have required delivery/pickup time windows, was addressed to FISC Puget Sound personnel during the visit to the site. None of the various HAZMINCTR sites has any particular time constraints other than normal working hours [Ref.3].

e. Material Handling Equipment (MHE)

The type of material handling equipment available at the origin and each delivery point will affect the total load and unload times and the time to separate any HAZMAT from HAZWASTE on the delivery vehicle.

FISC Puget Sound currently utilizes one 5000 pound forklift to move its HAZMAT from its receiving dock to its storage area and to transport any HAZWASTE between the delivery vehicles and its accumulation yard. Each HAZMINCTR site currently has at least one 2000 pound forklift to offload material and on load HAZWASTE. At this time additional capacity does not appear to be required.

f. Proposed Routes

Figure 5.2 shows the proposed delivery/pickup routes. Although there are numerous algorithms to optimize local delivery vehicle routing [Ref.17], the geographic factors in the Puget Sound area override many of the alternatives. The first route will service the HAZMINCTRs near the HAZMATCTR - Puget Sound Naval Shipyard (PSNSY); Submarine Base, Bangor Reuse Center and the Trident Refit Facility (TRF); and the Naval Undersea Warfare Center, Keyport (NUWC).

The second route would service the outlying HAZMINCTRS at NAVSTA Everett and NASWI. The necessity of proper planning and using the Washington State Ferry Service are key factors in developing service on this route. Ferries are only available from Kingston to Edmonds, Mulkiteo to Clinton (south edge of Whidbey Island), and Keystone (near

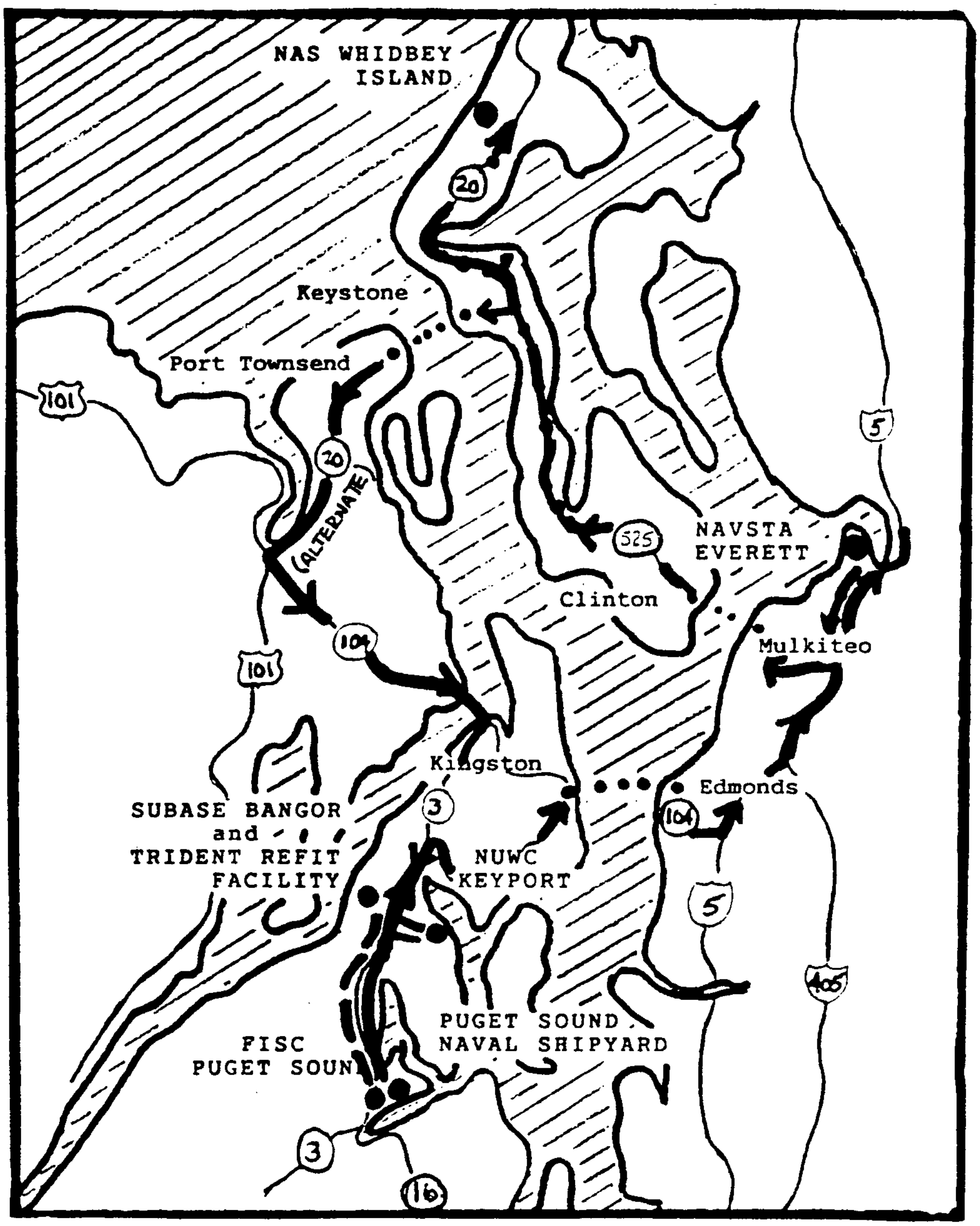

Figure 5.2. Proposed delivery/pickups routes.

NASWI) to Port Townsend (see Figure 5.2). The service would need to be flexible and adjusted according to the known HAZMAT and HAZWASTE requirements at the two sites. When there is sufficient space available for material being delivered to both sites and for all HAZWASTE to be picked up at both sites, it would be beneficial to operate this route as a loop, utilizing the ferry from Keystone to Port Townsend after visiting NASWI. When vehicle capacity dictates delivering first to NASWI, it would operate in the opposite direction. If vehicle capacity is at a premium, deliveries would be made on the outbound leg, pickups on the return leg. If no material is required or no HAZWASTE is ready for pickup at either site, this route would be omitted for that week. Minimizing travel time (which would minimize total cost per mile for the vehicle and the driver) would be given more significance in determining a specific weekly delivery/pickup.

There are several advantages to the proposed multiple routes. First, the capacity of the vehicles need only be as large as the amount of deliveries dictate for that route. Second, the need to segregate material from waste is minimized. Only HAZMAT being transferred from one HAZMINCTR to another (or in the situation outlined above for Everett and NASWI) would require segregation. The amount of vehicle space on the return leg also makes it is easier to segregate different types of waste within the vehicles.

Requirements for transporting HAZMAT and HAZWASTE by ferry are controlled by the Department of Transportation. Vehicles using the ferries must adhere to the same requirements as vehicles travelling over the road. No additional safety requirements must be met.

g. *Current System*

FISC currently has a 5-ton covered truck available to deliver material around FISC and PSNSY. For deliveries to all other sites they use a driver certified under 49 CFR [Ref.10] to transport HAZMAT over the road. The driver is supplied by either the nearby Manchester Fuel Depot or Defense Depot Public Works (DDPW) since FISC does not have their own certified driver. Deliveries are made 2 to 3 times a week, both on and off station. 90 percent of all deliveries are less than 2000 pounds. When the ferry system is not available due to inclement weather, the driver services the two outlying sites by road. This requires that he drive south along Highway 16 over the Tacoma Narrows Bridge, drive along the eastern shore of Puget Sound to reach NAVSTA Everett. From there he continues north along Interstate 5 to Highway 20, travels along this route through Anacortes, where the bridge through Deception Pass puts him at the north edge of Whidbey Island. His return trip retraces this route. Total one way driving time is at least 3 hours. Including unloading and reloading time, it is near impossible for him to deliver to all six sites in one day. The current cost of this service was not available to us. [Ref.18]

4. HAZMINCTR to End User Delivery System

Each HAZMINCTR is expected to have its own pickup and delivery service to customer activities within their area of operation. That system is expected to operate on a daily basis and will deliver material from HAZMINCTR stock to the user either upon request or on a regular daily delivery cycle. Each vehicle needs to be capable of carrying both HAZMAT and HAZWASTE and needs to comply with all regulations concerning separation [Ref.16]. Hazardous waste removed from customer activities would be stored at the HAZMINCTR and would be picked up by the HAZMATCTR delivery vehicle during its regularly scheduled cycle.

5. Cost Effect of Transportation

We are assuming that the majority of the transportation decisions, such as delivery route, size of trucks, and MHE requirements, will be made independent of the inventory management model. The inventory model will affect the schedule of delivery, which will depend on how often material ordered for distribution to the HAZMINCTRs exceeds the capacity at the HAZMATCTR receiving and storage facility. If the HAZMATCTR can coordinate with its suppliers to deliver material to coincide with the pre-determined network delivery schedule, this capacity constraint would also not be a factor. However, with the wide variance of lead times for order delivery from the supply system, this coordination is not yet available. However, current warehouse capacity is not constrained by the amount of material being received at FISC Puget Sound. Therefore, we assume none of these factors will affect the inventory management model in a steady state environment.

H. ENVIRONMENTAL CONSTRAINTS

Appendix D is the "Permit to Operate" issued by the Ventura County (California) Air Pollution Control District to the Naval Air Weapons Station, Point Mugu. As it illustrates, Point Mugu is severely restricted in the quantities of facilities, equipment, and material it may use in a given year that may pollute the atmosphere. Within the permit there are specific guidelines as to the maximum allowable amounts of various hazardous chemicals that may be used. This permit affects the inventory management decisions at Point Mugu. It is unwise for them to stock material in excess of the allowable amounts because it increases the potential for HAZWASTE disposal costs due to expired shelf life. For example, the permit restricts Point Mugu to an annual usage of 55 gallons of methylene chloride stripper containing less than 10 percent by weight reactive organic compounds (ROC).[4] There may be similar restrictions for Puget Sound. We were unable to procure one at this time. Although California currently has some of the more stringent environmental regulations, the state of Washington is also in the forefront of environmental reform and these restrictions obviously impact inventory management models.

[4]Methylene chloride is used primarily as a solvent for various organic materials, as a refrigerant in centrifugal compressors, and as an ingredient of non-flammable paint-removal mixture [Ref. 13: p. 747].

VI. MODEL DEVELOPMENT

A. INTRODUCTION

Having presented forecasting and cost concepts in the two preceding chapters, the foundation for an examination of how much to order and when to place the order to provide a desired level of customer service has been established. Two inventory models are proposed: an expanded Economic Order Quantity (EOQ) model and a modified version of the Silver model. The EOQ model assumes continuous review and the Silver model assumes periodic review.

B. EOQ MODEL

1. Background

The Economic Order Quantity (EOQ) model dates back to the early part of this century and is the basis for most commonly known deterministic inventory models [Ref.8:p.564]. The basic model determines an order quantity that balances holding and ordering costs and, as a consequence, minimizes total average annual variable costs. The EOQ model is easy to use but doesn't take into account risk and uncertainty [Ref.6:p.205]. The limitations of the assumptions accompanying the basic model add to its simplicity. How the important assumptions of the classic model and the assumptions of the model differ, and several additional assumptions for the model, are provided in the following paragraphs.

a. Demand is Known and Constant

This assumption is valid if we further project that as the HAZMATCTR and HAZMINCTRs approach steady-state operations the majority of demand will come from planned or MRP requirements as discussed in Chapter IV. The additional unknown, random component will be covered by safety stock. We cannot, however, assume that this demand will be constant. For the development of the model we will assume demand to be probabilistic and described by a steady-state known probability distribution (i.e., having a constant mean and variance over time).

b. Lead time is Known and Constant

By improving relations with GSA/DLA, the variability of lead times for receiving material can be reduced. Hopefully, this factor can approach a known, constant level. However, it is unlikely this will happen in the near future. Therefore, for the model lead times are assumed to be probabilistic.

c. Instantaneous Receipt

All material from an order is assumed to arrive at the same time. This is a normal circumstance for most small orders. We assume for modeling purposes that even for large orders all items arrive at the same time.

d. No Quantity Discounts are Available

There is no discount for larger orders of supply system stocked material. Although the quarterly price may increase with each new Management List, Navy (MLN) tape from the item managers, we assume a constant price.

e. All Costs are Known and Constant

We assume that all costs can be identified and will not change significantly over the forecast period.

f. Disposals Will be a Factor of Returned Material Only

This assumption is not part of the classic EOQ model, but, as discussed in Chapter V, it is an important consideration. Disposal of material is assumed to represent a fixed percentage of returned material. The actual disposal rate is a random variable consisting of both "A" condition and CA material, but until more information is known about its distribution it is assumed to be a constant factor of returned material only. Although, in reality, there is some disposal of "A" condition material, we were not able to find any. The cost of inspecting material for expired shelf life is assumed to be a component of the holding cost.

g. Demand and Lead Time are Independent and Normally Distributed

For ease of computations we are assuming that the probability distributions for the demand rate and lead time are Normal and are independent of each other. Hadley and Whitin [Ref.19:p.117] point out that for low demand items it is more probable that the demand rate will be described by a Poisson distribution. Further, they add that it is not unreasonable that lead time will follow a Gamma distribution. The convolution of a Poisson demand rate and a Gamma lead time will result in a Negative Binomial distribution for demand during lead time. However, since there is no current data, we have limited the model assumptions to a Normal distribution for the demand during lead time.

2. Model Development

a. Parameter Definitions for the Reorder Point

The following parameters are used. Lead time is expressed in days and demand and return rates are expressed in pounds per day.

D_{MRP} = Mean demand rate - MRP.

D_{RAN} = Mean demand rate - Random.

D = Mean demand rate - Total.

W = Mean return rate.

d_r = Decimal fraction of returns going to disposal.

D_{MRPLT} = Mean demand during lead time - MRP.

D_{RANLT} = Mean demand during lead time - Random.

D_{LT} = Mean demand during lead time - Total.

W_{LT} = Mean returns during lead time.

DIS_{LT} = Mean disposal quantity during lead time.

LT = Procurement lead time (days).

σ_{MRP} = Standard deviation of demand rate - MRP.

σ_{RAN} = Standard deviation of demand rate - Random.

σ_{D} = Standard deviation of demand rate - Total.

σ_{W} = Standard deviation of return rate.

σ_{LT} = Standard deviation of lead time.

σ_{MRPLT} = Standard deviation of lead time demand - MRP.

σ_{RANLT} = Standard deviation of lead time demand - Random.

σ_{LTD} = Standard deviation of lead time demand - Total.

σ_{WLT} = Standard deviation of returns during lead time.

σ_{DISLT} = Standard deviation of disposals during lead time.

z = Standard Normal distribution deviate.

SS = Safety stock

ROP = Reorder Point for the HAZMATCTR.

Using these parameters, mean lead time demand, mean returns during lead time, and mean disposals during lead time are defined as follows:

$$D = D_{MRP} + D_{RAN} \; ; \tag{6.1}$$

$$D_{MRPLT} = D_{MRP}\, LT \; ; \tag{6.2}$$

$$D_{RANLT} = D_{RAN}\, LT \; ; \tag{6.3}$$

$$W_{LT} = W\, LT \; ; \tag{6.4}$$

$$DIS_{LT} = d_{r}\, W_{LT} \; ; \tag{6.5}$$

and, consequently,

$$D_{LT} = D_{MRPLT} + D_{RANLT} = D\, LT \; . \tag{6.6}$$

Next, we define the standard deviations for the components. The general formula for the standard deviation for lead time demand is given by equation (6.7) [Ref.6:p.231]:

$$\sigma = \sqrt{D^2 \sigma_{LT}^2 + LT \sigma_D^2} \; . \tag{6.7}$$

The equations for determining the standard deviation for each of the different types of demand are therefore:

$$\sigma_{MRPLT} = \sqrt{D_{MRP}^2 \sigma_{LT}^2 + LT \sigma_{MRP}^2} \; ; \tag{6.8}$$

$$\sigma_{RANLT} = \sqrt{D_{RAN}^2 \sigma_{LT}^2 + LT \sigma_{RAN}^2} \; ; \tag{6.9}$$

$$\sigma_{WLT} = \sqrt{W^2 \sigma_{LT}^2 + LT\sigma_W^2} \;; \tag{6.10}$$

$$\sigma_{DISLT} = \sqrt{d_r^2 \sigma_{WLT}^2} \;. \tag{6.11}$$

And, since the variance of a sum of independent random variables is the sum of the variances,

$$\sigma_{LTD} = \sqrt{\sigma_{MRPLT}^2 + \sigma_{RANLT}^2 + (1 + d_r^2)\,\sigma_{WLT}^2} \;. \tag{6.12}$$

b. Reorder Point

The Reorder Point or Low Limit for this model, ROP, is the average demand during procurement lead time plus some level of safety stock based on the customer's desired service level. For a Normal distribution this can be expressed as [Ref.6:p.227]:

$$ROP = D_{LT} + z\,\sigma_{LTD} \;; \tag{6.13}$$

where $z\sigma_{LTD}$ is the Safety stock (SS).

Next, we substitute for D_{LT} and σ_{LTD} to establish the HAZMATCTR reorder point. The result is:

$$ROP = D_{MRPLT} + D_{RANLT} - W_{LT} + DIS_{LT} + SS \;. \tag{6.14}$$

where,

$$SS = Safety\;Stock = z\sqrt{\sigma_{MRPLT}^2 + \sigma_{RANLT}^2 + (1 + d_r^2)\,\sigma_{WLT}^2} \;. \tag{6.15}$$

c. Parameter Definitions for the Order Quantity

Quantities are in pounds.

Q = Order Quantity.

C_P = Procurement cost of the item, $ per unit.

C_D = Cost of disposal, $ per unit.

R = Mean annual demand (equal to the mean demand rate, **D**, times the number of working days per year, at least 260).

Y = Mean annual returned quantity (equal to the mean daily return rate, **W**, times number of working days per year, at least 260).

I = Annual holding cost fraction, as a percent of item cost.

A = Cost per order, $.

λ = Cost of a backorder, $ per unit.[5]

d. Order Quantity

The Order Quantity for this model is dependent on the average Annual Total Variable Cost (TVC). We wish to find the order quantity that minimizes TVC. For this model the TVC equation can be defined as [Ref.6:p.104]:

TVC = Purchase Cost + Ordering Cost + Holding Cost + Backorder Cost + Disposal Cost[6]

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[5]As discussed in Chapter V, this cost will be implied by the desired RISK.

[6]Disposal cost of CA material only.

Each of the five annual variable cost components of TVC is defined below in a separate equation.

(1) Purchase Cost. The average annual Purchase Cost is equal to the unit cost of the item multiplied by the net annual average demand. This cost is not a function of Order Quantity, but is dependent on yearly demand. We are assuming that the HAZMATCTR will be able to fully meet annual demand by the customer. The equation for this cost is:

$$C_p\,[R - Y(1-d_r)]\ . \tag{6.16}$$

(2) Ordering Cost. The average annual Ordering Cost is equal to the cost per each order multiplied by the average number of order cycles in a year. The number of order cycles per year is found by taking the net annual average demand and dividing it by the order quantity. Equation (6.17) describes this cost. The term within the brackets is the average number of order cycles in a year.

$$A\,[\frac{R - Y(1-d_r)}{Q}]\ . \tag{6.17}$$

(3) Holding Cost. The average annual Holding Cost is equal to sum of the average annual on-hand inventory multiplied by the annual holding cost per unit. Average annual on-hand inventory is equal to the sum of the safety stock and half of the order quantity. Annual holding cost per unit equals the annual holding cost fraction multiplied by the unit cost of each item. The equation for holding cost is:

$$IC\,[\frac{Q}{2} + SS]\ . \tag{6.18}$$

(4) Backorder Cost. The average annual Backorder Cost is equal to the cost of a backorder multiplied by the expected number of backorders likely to occur during an order lead time. This figure is then multiplied by the average number of order cycles that occur per year to get the annual cost. The equation for this cost is:

$$\lambda \left[\frac{R - Y(1-d_r)}{Q} \right] \left[E(D_{LT} > ROP) \right] , \qquad (6.19)$$

where $E(D_{LT} > ROP)$ is the expected stockouts, in units, during lead time. This is the expected amount by which demand during procurement lead time will exceed the reorder point. It is a function of the HAZMATCTR's desired service level which determines the RISK factor that is acceptable and governs the safety stock level. For a Normal distribution, this equation can be written as [Ref.6:p.216]:

$$E(D_{LT} > ROP) = \int_{ROP}^{\infty} (D_{LT} - ROP)\, f(D_{LT})\, dD_{LT} . \qquad (6.20)$$

where $f(D_{LT})$ is the probability density function for demand during lead time.

(5) Disposal Cost. The average annual Disposal Cost is equal to the cost of disposal for each item multiplied by the average amount of material disposed of per year. We are assuming this amount is a fixed percentage of the amount of material returned. The equation for this cost is:

$$C_D \, Y \, d_r . \qquad (6.21)$$

(6) Total Average Annual Variable Cost.

Introducing equations (6.16) through (6.19) and (6.21) into the Total Average Annual Variable Cost equation results in equation (6.22).

$$TVC = C_P\,[R - Y(1-d_r)] + A\,[\frac{R - Y(1-d_r)}{Q}] \tag{6.22}$$

$$+ IC_P\,[\frac{Q}{2} + SS] + C_D\,Y\,d_r$$

$$+ \lambda\,[\frac{R - Y(1-d_r)}{Q}]\,[E\,(D_{LT} > ROP)]\ .$$

(7) Determining the Optimal Order Quantity. Taking the first derivative of TVC with respect to Q, setting it equal to zero, and solving for Q provides the following equation for the optimal Order Quantity [Ref.6:p.93]:

$$Q = \sqrt{\frac{2\,[R - Y(1-d_r)]\,[A + \lambda\,E(D_{LT} > ROP)]}{IC_P}}\ . \tag{6.23}$$

e. *High Limit*

Finally, the High Limit is equal to the sum of the Reorder Point equation (6.14) and the Order Quantity equation (6.23); that is:

$$HIGH\ LIMIT = ROP + Q\,. \tag{6.24}$$

C. MODIFIED SILVER MODEL

1. Background

The Modified Silver model was proposed by Lieutenant G. C. Robillard as a modification to E. A. Silver's model for a situation that involves probabilistic demand with a time varying mean.[7] This model is based on periodic review, while the previous model is continuous review.

The Silver model [Ref.20] is a lot-sizing algorithm based on the least total variable costs per unit time approach. It deals with the problem of how to determine the timing and sizes of the replenishments of an item having probabilistic demand with a mean value that varies significantly over time. It also assumes a known replenishment lead time of a specified duration [Ref.20:p.372].

Robillard's version of this model, known here as the Mod-Silver model [Ref.21], takes the algorithm a step further by assuming that lead times, rather than being deterministic, are stochastic in nature. It closely resembles a periodic review model, since Robillard assumes a fixed time between reviews of the current inventory position [Ref.21:p.19]. The assumptions made under this model are:

1. Calendar time is divided into fixed time periods of the same length. Reviews will be conducted at the end of each period and orders arrive at the start of a period.

2. Procurement lead time is Normally distributed and the mean and standard deviation can be estimated.

3. Demand forecasts exist for each period in a specified forecast time horizon. The length of the forecast

[7]Probabilistic demand implies that there exists some measure of forecast error. Silver suggests that it is reasonable to use a deterministic model to select the order quantity (or period to be covered) and superimpose a safety stock sufficient to meet the desired level of service [Ref. 3: p. 374]. This is also what we are suggesting in our continuous review model described above.

horizon is constrained by the DOD constraint which limits the maximum reorder amount to the expected demand over 6 quarters [Ref.21:p.24].[8]

4. The selection of a reorder point does not depend on the value of maximum inventory to be used. Instead, it depends on the determination that adequate service can be provided if the placing of an order is delayed until at least the next review point [Ref.20:p.373].

5. Demand forecast errors are Normally distributed for a time interval equal to the mean lead time plus one fixed review period.

6. Holding and ordering costs are the only relevant costs. Like the Silver model, holding costs are charged only on inventory carried from one period to another.

7. Demand occurs at the beginning of each review period so no holding cost is incurred on this material during the period immediately following the review.

8. Safety stock is determined based on a desired customer service level. This stock acts as a buffer against larger-than-expected lead time demand.

9. Outstanding orders do not cross in time; orders are received sequentially.

Robillard's model considers holding and ordering costs to be the only relevant costs [Ref.21:p.24]. His model omits holding costs of returned material, disposal costs, and shortage costs. We are adding the following assumptions to the Mod-Silver model to adjust for these costs:

10. Return of CA material occurs at the beginning of each review period.

11. Disposals occur before the return material is brought back into stock. No holding cost is therefore incurred on that material.

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[8]Since our model will assume review periods of one week, this number becomes 78 weeks (6 quarters multiplied by 13 weeks per quarter).

12. Forecasts for returns exist for each period in a specified forecast time horizon.

13. The number of returns is Normally distributed for a time interval equal to the mean lead time plus one fixed review period.

14. Shortage costs exist but are unknown; they are solved for implicitly by using a level of service (as discussed in Chapter V).

2. Model Development

a. Parameter Definitions

In addition to the parameters in Section B.2 above, the following additional parameters are required and correspond to those in Reference 21:

$\mathbf{t_0}$	=	Time of the current review.
IP	=	Inventory position at the time of the current review.
L	=	Mean lead time (in periods).[9]
T	=	Order interval. Number of periods that the current order is expected to cover (an integer).
$\mathbf{k_a}$	=	Actual safety stock factor based on the current inventory position if an order is not placed (represents a Normal deviate).
$\mathbf{k_r}$	=	Required safety stock factor (set by policy) at the current review point to meet demand for L+1 periods (also represents a Normal deviate).
τ	=	Random variable that represents the lead time.

[9]Mean lead time for the Mod-Silver (L) is expressed in review periods, where mean lead time for the EOQ (LT) is expressed in days. The review period in this problem is weekly.

X1 = Forecasted demand over the time interval t_0 to L+1.

X2 = Forecasted demand over the time interval t_0 to T-1.

X3 = Forecasted demand over the time interval T-1 to L+T.

σ_i = Standard deviation of forecast error for the i_{th} period.

σ_{X1} = Standard deviation of forecast error over the time interval X1.

σ_{X2} = Standard deviation of forecast error over the time interval X2.

σ_{X3} = Standard deviation of forecast error over the time interval X3.

b = Safety stock coefficient (factor of X2).

c = Coefficient of variation.

d_i = Forecasted demand for the i_{th} period.

$\bar{d}_{X1}$ = Average demand for the time interval X1.

σ_T^2 = Variance of procurement lead time.

Figure 6.1 represents the various time intervals involved in the modified Silver model [Ref.21:p.21].

b. Reorder Point

Since this model takes on the appearance of a periodic review system (vice a continuous review reorder point system), it is important to determine the actual probability of a stockout at the time of review. This probability is based on the fact that, if an order is not placed at time t_0, the current inventory position must be able to provide for actual demand during a time interval of length L + 1, which is the expected order receipt if an order is not placed until the next review (t_0 + 1). This actual safety factor can be measured as [Ref.21:p.22]:

$$k_a = \frac{IP - X1}{\sigma_{X1}} \quad (6.25)$$

The required safety factor, k_r , depends on the service level specified by the item manager [Ref.21:p.22].[10] An order should be placed at the current review, time t_0, if k_a is less than k_r at t_0. When this occurs, it implies that the actual safety factor is insufficient to provide the desired level of service for the next L+1 periods [Ref.21:p.23].

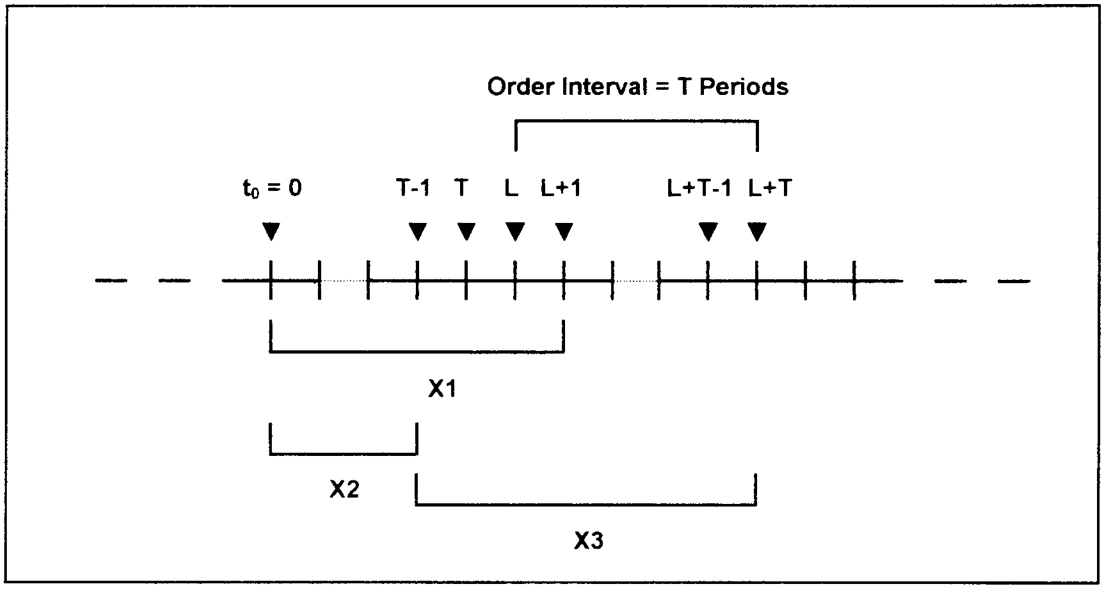

Figure 6.1. Time Sequence, Forecast Intervals, and Forecasted Demands.

The standard deviation of demand over the next L+1 periods can be written as:

[10]Both k_a and k_r represent standard Normal deviates under the assumptions of our model. In this problem, the required safety factor is set by the HAZMATCTR and was previously defined as 1 - RISK. It is assumed to be 99% for this discussion. 99% of the area under the standard Normal curve is found 2.33 standard deviations to the right of the mean. Thus, k_r equals +2.33 and an order should be placed whenever k_a is less than 2.33 at time t_0.

$$\sigma_{X1} = \sqrt{\sum_{i=1}^{L+1} \sigma_i^2 + \bar{d}_{X1}^2 \sigma_\tau^2} \, , \tag{6.26}$$

where i=1 is the first period following t_0 [Ref.21:p.23].

c. Order Interval

The Order Interval is determined by the use of the Silver-Meal heuristic [Ref.22:Ch.8]. The heuristic selects the lowest integer value of T such that the total relevant costs per unit time for the duration of the replenishment quantity are minimized (the replenishment quantity being the total demand during the interval that the current order is expected to cover). The Total Relevant Cost per unit time is determined by:

$$TRCUT(T) = \frac{A + IC_p \sum_{i=1}^{T} (i-1)\, d_i}{T} \, . \tag{6.27}$$

Since the Silver-Meal heuristic selects T corresponding to the first minimum which occurs, this is not necessarily a global minimum. However, the Mod-Silver selects the value of T which minimizes TRCUT(T) from among the values 1 to 78. (DOD limits the maximum reorder amount to the expected demand over 6 quarters and the time interval between reviews is assumed to be a week.) This guarantees a minimum over the constrained forecast horizon of 78 weeks [Ref.21:p.24].

d. Order Quantity

The Order Quantity (Q) and hence the High Limit are dependent on the length of the order cycle (T). As Robillard illustrates, two distinct possibilities exists: 1) T = one period, and 2) T > 1 [Ref.21:p.24].

When the order cycle equals one time period (T = 1), the Order Quantity is defined as [Ref.21:p.25]:

$$Q = X1 + k_r \sigma_{X1} - IP \ . \tag{6.28}$$

This equals the sum of the expected average demand for the interval and the required safety level minus the inventory position at the current review. Figure 6.2 illustrates this situation [Ref.21:p.25].

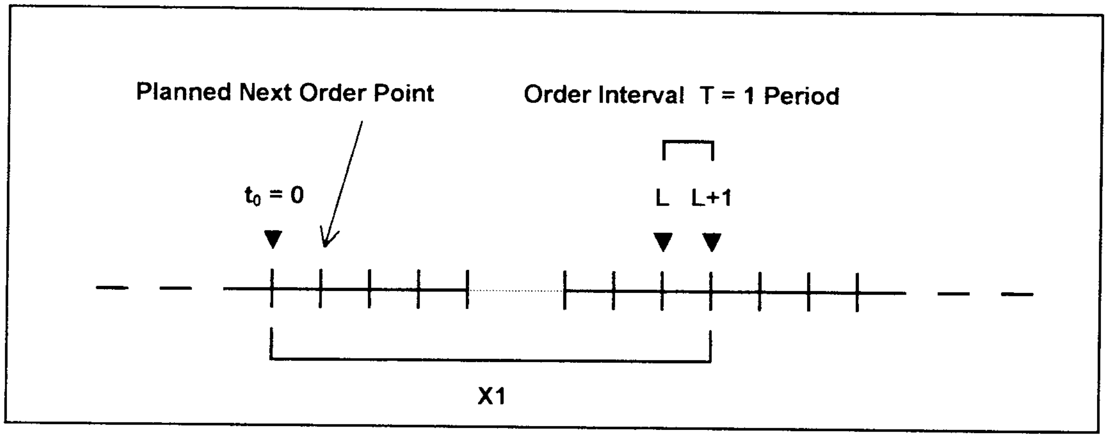

Figure 6.2. Order Interval for T=1.

The situation when the order interval is greater than one period (T > 1) is illustrated by Figure 6.3 [Ref.21:p.25]. The model needs to account for the possibility that, although the next order is planned at T periods after the current period, during the periodic reviews a situation is reached where $k_a < k_r$ at a time less than T. This would require a small order to be placed at that time. To reduce the potential for this situation, the model includes a safety buffer which is a multiple of the standard deviation of

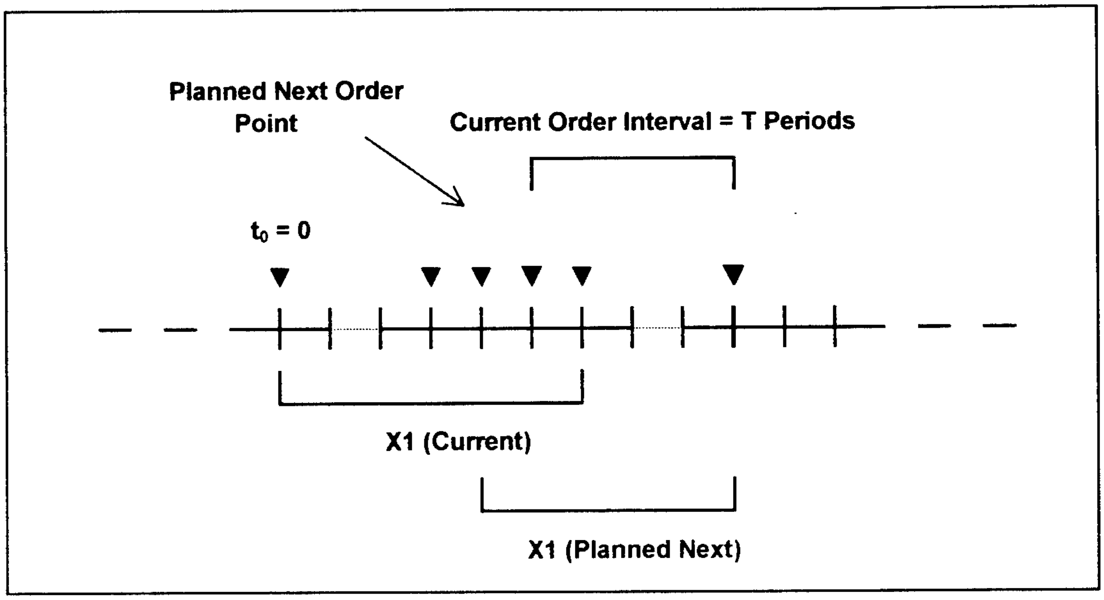

Figure 6.3. Order Interval for T > 1.

interval of concern; in this case, X2. Robillard expresses the Order Quantity in this situation as [Ref.21:p.27]:

$$Q = X2 + b\sigma_{X2} + X3 + k_r\sigma_{X3} - IP \ . \tag{6.29}$$

The factors of this equation are defined as follows:

$X2 + b\sigma_{X2}$ = the expected demand for the interval t_0 to T-1; this is the period up to, but not including, the next planned reorder review plus the additional safety stock buffer, a multiple (represented by **b**) of the measure of uncertainty of forecast errors over this time interval.[11]

[11] **b** is a Normal deviate value set by the activity that must determine how much additional safety stock buffer is needed to prevent the possibility of too many stockouts. The actual value represents a trade-off of the different cost factors involved; i.e., the additional carrying costs and ordering costs compared to the costs expected as a consequence of running out of stock. Silver recommends that little, if any, buffer should be considered

$X3 + k_r\sigma_{X3}$ = the forecasted demand over the interval T-1 to L+T; this is the interval from just prior to the next planned reorder to the expected delivery of the next planned reorder) plus the safety stock: the required safety factor (set by policy) multiplied by the measure of uncertainty of the forecast errors over this time interval.

As shown in Equation (6.29), we subtract from the sum of these factors the inventory position at the current review time, **IP** , to obtain the order quantity.

The standard deviations corresponding to the intervals X1, X2, and X3 are estimated as follows [Ref.21:p.29,32]:

$$\sigma_{X1} = \sqrt{c^2 \sum_{i=1}^{L+1} d_i^2 + \bar{d}_{X1}^2 \sigma_\tau^2} \; ; \qquad (6.30)$$

$$\sigma_{X2} = c\sqrt{d_1^2 + d_2^2 + \ldots + d_{T-1}^2} \; ; \qquad (6.31)$$

$$\sigma_{X3} = \sqrt{c^2 \sum_{i=1}^{L+T} d_i^2 + \bar{d}_{X3}^2 \sigma_\tau^2} \; . \qquad (6.32)$$

These represent the degree to which there is potential error in the forecast for each of the three intervals. These

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since the cost penalty in the Silver-Meal heuristic (the basis for determining the order interval) is not severe for using T-1 instead of the best T [Ref.20:p.375]. Robillard used simulation to expand on this principle and states that he found very small cost penalties for small buffer values (b=0 to 0.9), although his simulation did not seek to optimize the value [Ref.21:p.68]. Based on Robillard's findings, we use a **b** value of 0.5 for our examples, which represents the value of the Normal deviate associated with a stockout probability of approximately 31%, which means additional buffer stock is added to cover slightly less than 70% of the expected demand over the interval with a mean demand of X2.

estimates assume that the coefficient of variation, or the ratio of the standard deviation of forecast error of a single period to its mean (forecast), is constant over the forecast horizon [Ref.21:p.28]. The estimate of the coefficient of variation **c** can be expressed:

$$c = \frac{1.25\,(MAD_1)}{d_1}\ , \tag{6.33}$$

where MAD_1 represents the forecast mean absolute deviation of demand for the next period and d_1 is the next period's demand forecast.

3. Relating the Model to the HAZMATCTR

To relate the Mod-Silver model to the HAZMATCTR concept, several additional issues need to be addressed.

a. Deterministic Demand

The lack of current data makes accurate demand forecasting difficult. We assume that an approximately steady state deterministic demand will evolve as MRP requirements become the focus of customer activity. When that occurs the Mod-Silver model should work extremely well. Until that time, although MRP requirements continue to evolve, random demand will still exist.

b. Average Demand Per Period

Average (mean) demand per period must be forecast for "A" condition material. In addition, forecasts of the average return rate per period for CA material and the average disposal rate per period are needed. We assume at present that disposal is a fixed percentage of returns. Net mean demand per period, $\mathbf{d_i}^*$, is the mean demand for "A" condition material minus the mean amount of this demand that is satisfied with CA material that has been received back from customers. This CA material is adjusted to reflect the fixed percentage of material that will be disposed of. Symbolically, this equation can be written as:

$$d_i^* = d_i - w_{i-1}(1 - d_r) \ . \tag{6.34}$$

Here d_i equals the expected demand for "A" condition material for the period i and w_{i-1} equals the expected returns for period i-1. Since unused material is to be returned to the HAZMINCTR (and be placed back on the inventory records) within one week, this material should be available to fulfill demand requirements before the next review period.

c. Costs

As mentioned in Section C, Robillard's model omits other costs relevant to the HAZMAT problem. We consider each of the three additional cost components of the TRCUT(T) formula below.

(1) Holding Costs. To account for the additional holding costs for material that is returned we revise the holding cost term of the current TRCUT(T) formula to be:

$$h[\sum_{i=1}^{T}(i-1)\,|d_i^*|] \ . \tag{6.35}$$

The absolute value of d_i^* accounts for periods when mean returns exceed mean demands. During periods when returns exceed demand no additional material will be ordered but will still incur holding costs because the CA material is not being disposed of.[12]

(2) Disposal Costs. Disposal costs are handled in a similar manner to holding costs. In a steady-state environment it is hoped that disposal costs approach zero, because of improved planning by the HAZMAT users, but realistically it is unlikely. Additionally, the marginal cost to dispose of an unit of material will continue to rise as the nation becomes more environmentally concerned. To completely disregard these costs is dangerous to the effective operation of the HAZMATCTR concept. The additional cost term is therefore:

$$C_D\,[\sum_{i=1}^{T}(w_{i-1})\,d_r] \ . \tag{6.36}$$

(3) Shortage Costs. For shortage costs, we have identified an implied cost of stockout, λ, for each item. By multiplying this implicit cost by the expected value of the amount that the cumulative net demand from the time of the review to the receipt of the next planned order (time interval L+T) exceeds the cumulative net mean demand if an order was placed now, and subtracting the inventory position at the time of the review, we can calculate a shortage cost for each period. This factor can be written as:

$$\lambda\,[E(\sum_{i=1}^{L+T}d_i^* > [(X2+b\sigma_{X2}) + (X3+k_{X2})])] \ . \tag{6.37}$$

---

[12]Since average demand and average returns can be forecast with some certainty, the HAZMATCTR will some idea when demand will be met by returned material and there will be no need to order "A" condition material.

The terms of this equation are defined as follows:

$$\sum_{i=1}^{L+T} d_i^* \tag{6.38}$$

is the cumulative net demand between the time of the order to the receipt of the next planned order.

$$[(X2+b\sigma_{X2})+(X3+k_r\sigma_{X3})] \tag{6.39}$$

is the mean expected demand from the interval t_0 to L+T plus the safety stock buffers for the period. This is the value of the maximum inventory level at time t_0.

d. Proposed Adjusted TRCUT(T) Formula

The proposed TRCUT(T) formula with the additional cost factors included is as follows:

$$\frac{A+h[\sum_{i=1}^{T}(i-1)\,|d_i^*|]+C_D[\sum_{i=1}^{T}(w_{i-1})\,d_r]+\lambda[E(\sum_{i=1}^{L+T}d_i^*>(X2+k_r\sigma_{X2})+(X3+b\sigma_{X3}))]}{T} \tag{6.40}$$

D. CONCLUSION

In this chapter we have formulated two inventory models that could be used to manage the inventory of hazardous material at the HAZMATCTR. The lack of current data is a major problem in assessing the validity of either model. In the next chapter we provide numerical examples of both models using hypothetical data to provide a sense of how they compare in minimizing the variable inventory management costs.

VII. MODEL EXAMPLES

A. INTRODUCTION

In Chapter VI we presented two possible models for incorporation into the HAZMATCTR concept to manage hazardous material inventory. These models represented two types of inventory systems: a continuous review model and a periodic review model. In this chapter we provide examples of these models in an effort to illustrate their use. All data is hypothetical.

B. THE CONTINUOUS REVIEW MODEL EXAMPLE

For this example the following information is assumed.

Demand during Lead Time is Normally Distributed.

The item is a standard stock item.

D_{MRPLT}	= 35 lbs
σ_{MRPLT}	= 12 lbs
D_{RANLT}	= 9 lbs
σ_{RANLT}	= 5 lbs
W_{LT}	= 3 lbs
σ_{WLT}	= 2 lbs
d_r	= 5%
R	= 458 lbs per year
Y	= 25 lbs per year
A	= $54 per order
λ	= $198 per stockout
I	= 20% per year
C_P	= $10 per unit

Service Level (SL) per order cycle = 99%

Standard Normal Deviate for SL equals 99% = 2.33

Lead time = 5 weeks

1. **Step 1. Determine the Reorder Point (ROP)**

In determining the reorder point, equations (6.14) and (6.15) must be used. Given the above data the safety stock and reorder point are calculated as follows:

$$\boldsymbol{SS} = 2.33 * \sqrt{12^2 + 5^2 + (1+0.05^2)2^2} = 2.33 * 13.15 = 30.65\ lbs;$$

$$\boldsymbol{ROP} = 35 + 9 - 3 + 0.05*3 + 30.65 = 71.80\ lbs.$$

2. **Step 2. Compute $E(D_{LT}>ROP)$**

As determined in Step 1, the standard deviation of lead time demand is 13.15. Entering Table 5.3 of Reference 6 with the Standard Normal Deviate, E(Z) can be determined as 0.0035. E(Z) is the partial expectation given by the following equation, which will be used to determine $E(D_{LT}>ROP)$.

$$\boldsymbol{E(Z)} = \frac{\boldsymbol{E(D_{LT} > ROP)}}{\boldsymbol{\sigma_{LTD}}};$$

$$\boldsymbol{E(D_{LT}>ROP)} = E(Z)\,\sigma_{LTD} = (0.0034)(13.15) = 0.045.$$

3. **Step 3. Determine the Order Quantity (Q)**

To determine the order quantity, Q, equation (6.23) is used.

$$Q = \sqrt{\frac{2\ [458 - 25(1-0.05)]\,[54 + (198)(0.01)]}{(0.20)(10)}} = 155.90\ lbs.$$

4. Step 4. Determine the High Limit (HL)

The high limit is simply the sum of Q and ROP; that is,

$$HL = 71.78 + 155.90 = 227.68\ lbs\ .$$

C. THE PERIODIC REVIEW MODEL EXAMPLE

This example assumes the same data as the previous example. In addition, it assumes:

Period Length = 1 week

$\mathbf{t_o}$ = Period 2

b = 0.50

I = 0.385 % per period (equivalent to 20% per year)

$\mathbf{C_D}$ = \$2 per lb

IP = 60 lbs

σ_{X1} = 6 lbs

σ_{X2} = 10 lbs

σ_{X3} = 3 lbs

$\mathbf{k_r}$ = 2.33 (corresponding to a SL = 99% per order cycle)

Demands and returns are assumed to be those given in the following table. The demand data generated is random with a mean of ten pounds per week, which is similar to the continuous review example. The whole idea of the data is to illustrate how the periodic review model operates and is not intended to signify actual data or be precisely equivalent to the demand in the continuous review model example.

One important aspect of the Mod-Silver model is that it can easily handle highly variable known or approximately known demand. The continuous review model is not designed to handle known variable demand.

Period	d_i	w_{i-1}* $(1-d_r)$	d^*_i	Period	d_i	w_{i-1}* $(1-d_r)$	d^*_i
1	10	0	10	16	6	0	6
2 (t_o)	14	4	10	17	11	2	9
3	8	1	7	18	13	3	10
4	2	2	0	19	11	0	11
5	5	0	5	20	5	2	3
6	14	2	12	21	9	3	6
7	12	3	9	22	3	2	1
8	9	5	4	23	16	1	15
9	13	2	11	24	9	2	7
10	15	4	11	25	10	1	9
11	19	6	13	26	14	0	14
12	3	3	0	27	13	2	11
13	8	0	8	28	7	1	6
14	17	4	13	29	9	0	9
15	13	1	12	30	15	2	13

Table 7.1. Sample Demand Data.

1. Step 1. Determine the Order Interval (T)

As explained in Chapter VI the order interval is determined by the use of the Silver-Meal heuristic. Solving for the optimal order interval involves using equation (6.40) and assuming T=1, then T=2, then T=3, etc. The optimal order interval was determined to be 21 periods (weeks). The steps of the repetitive and tedious process to obtain this value are not provided.

2. Step 2. Solve for the Expected Demand Variables X1, X2, and X3

The expected demand over the interval from t_o (period 2) to L+1 (period 8) is 47 lbs, which represents X1. X2, which is the expected demand from t_o (period 2) to T-1 (period 21), is 160 lbs. The forecasted demand over the interval from T-1 (period 21) to L+T (period 27) is 63 lbs, which represents X3.

$$\boldsymbol{X1} = 10+7+0+5+12+9+4 = 47\ lbs;$$

$$\boldsymbol{X2} = 10+7+0+5+12+9+4+11+11+13+0+8+13+12+6+9+10+11+3+6 = 160$$

$$\boldsymbol{X3} = 6+1+15+7+9+14+11 = 63\ lbs.$$

3. Step 3. Solve for the Standard Deviations of X1, X2, and X3

The standard deviations of expected demand are determined using equations (6.30), (6.31), and (6.32) for X1, X2, and X3, respectively. Rather than going through those tedious estimates using fictional data we merely assumed the values for σ_{X1}, σ_{X2}, and σ_{X3} listed at the beginning of this section.

4. Step 4. Determine if a Reorder is Required

An order is required when the actual safety factor, k_a, is less than or equal to the required safety factor, k_r. For this particular example, equation (6.25) gives a value for k_a of 2.167 which is less than the required safety factor of 2.33 so a reorder is recommended.

$$\boldsymbol{k_a} = \frac{\boldsymbol{IP - X1}}{\boldsymbol{\sigma_{X1}}} = \frac{60 - 47}{6} = 2.167.$$

5. Step 5. Determine How Much To Order

Determining the amount to order is determined by using equation (6.29). For this particular example, the order quantity is 175 pounds of material.

$$\boldsymbol{Q} = 160 + (0.50)(10) + 63 + (2.33)(3) - 60 = 175 \ lbs$$

D. COMPARISON OF THE CONTINUOUS AND PERIODIC REVIEW MODELS

The two examples show a sample solution for the continuous and periodic review models and can be used to draw an approximate comparison between the two models. The maximum quantity on hand in the continuous model is the HL of 228 pounds while the maximum onhand for the periodic model is the order quantity plus the current inventory position or 235 pounds. The order quantities are also similar with less than a 15% (20 pounds) difference. The average order cycle for the continuous model shows an order cycle of about 18 weeks which compares favorably with the periodic model (which was 21 weeks). While these comparisons are not meant to sway the user toward one of the two models, they show that additional study is needed using actual demand data. The comparison depends heavily on the d_i values selected in Table 7.1. It is expected that as d_i approaches the forecasted mean demand rate of the continuous model, both models should produce nearly equal results. Conversely, as demand becomes more variable, the results can be expected to diverge.

E. CONCLUSIONS

As shown in the above examples, the continuous review model is probably the easiest to use, but neither of these models is math intensive and could be easily programmed into a spreadsheet program on a personal computer. For a more meaningful comparison of the two models actual data must be available. Only after such a comparison can an adequate decision be made as to which to use for the Hazardous Material Minimization Center Concept.

VIII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

Chapter II presents an overview of some of the Navy's current HAZMAT activities in operation on the West Coast at Point Mugu and in the Puget Sound area. Chapter III presents am examination of the data files within the HICS system and discusses 42 months of Point Mugu's data and its usefulness in forecasting. Detailed examination revealed that the data was not intended to provide information for inventory modeling purposes, but was used and accumulated to provide hazardous material control. Once we determined that the data was incomplete, we decided to approach the inventory management problem from a theoretical standpoint. Chapter IV presents a theoretical approach to forecasting demand and lead time for the proposed Hazardous Material Minimization Center Concept. Chapter V presents a detailed analysis of the applicable variable costs associated with that Concept. Chapter VI presents a continuous and a periodic model for determining optimal high and low levels for hazardous material inventory management and Chapter VII presents an example applying each of those models.

While the ideas presented in this thesis may not be the ultimate solution to the problem, they provide an excellent starting point for minimizing inventory management costs for a given customer service level for hazardous material inventories.

B. CONCLUSION

After examining the HAZMAT systems in operation and attempting to develop useful inventory management techniques for managing hazardous material, we feel and the research shows that the Hazardous Material Minimization Concept used in conjunction with a modified (incorporating demand forecasting techniques and inventory levels optimization) and fully utilized HICS system can be very effective in dealing with the Navy's hazardous material problem. The reasons for this conclusion are multifaceted:

1. The envisioned system is simply an extension of the Point Mugu system and the startup problems at Puget Sound can easily be overcome at other sites because of the knowledge gained by the Point Mugu system.

2. An inventory safety stock savings can result from stock consolidation via the regional concept and from recording demand for like items under a common stock number.

3. The HICS system has been mandated by the Navy for afloat operations and its use throughout the Navy can provide continuity and standardization for all Navy personnel, both civilian and military.

4. Either of the recommended inventory models and the suggested forecasting techniques can be accomplished easily utilizing a spreadsheet program and a personal computer which should permit easy incorporation directly into the HICS program with minimal programming effort and minimal capital investment.

C. RECOMMENDATIONS FOR DATA COLLECTION

1. Begin collecting demand data from all customers in the Puget Sound region immediately. The data should be segregated into the following categories: material needed for preventive or planned maintenance, material needed for emergent or corrective maintenance, material returned after issue, "A" condition material issued, cost avoidance material issued, demand for out of stock material, and material disposed of because of shelf-life expiration. Additional data that should be collected by FISC Puget Sound include actual order costs and actual disposal costs. The data should be collected and collated in weekly periods, by pound weight, and by stock number. Lead time data should also be collected both for orders for stock and direct turnover to customers.

2. A system to cross reference like items with different stock numbers must be developed and implemented into the next version of HICS as an add-on. This would allow consolidation of demand for like items and will provide increased customer service because of the additional stock visibility; especially of reuse material.

3. Material received by the individual HAZMINCTRs from the HAZMATCTR should be identified with a bar-coded number upon receipt and that number should be retained with that particular can or container from receipt through disposal of the contents of the container to ensure true cradle to grave tracking. This will allow identification of any material with a soon-to-expire shelf-life and a built in "tickler" system to ensure adequate turnover of inventory. This can be accomplished in the HICS system by an automatic sort feature by shelf-life dates. Because of the bar-coding that material can be easily be identified. While understanding that this would expand the memory needed for the computer systems, it should easily be managed with a medium sized hard disk drive. The HICS system uses less than 20 megabytes of hard disk space upon installation. If more memory is required a one gigabyte hard drive can be purchased for less than $700. For example, the entire compressed database for Point Mugu's system from birth in January of 1991 through June of 1994 fit on one three-and-a-half inch high density floppy disk (1.4 Megabytes) and consisted of about 25,000 records covering 1500 different stock numbers. The main network server at FISC, Puget Sound has a two gigabyte hard drive and is easily expandable [Ref.3].

D. FURTHER DEVELOPMENT/RESEARCH TOPICS

This thesis examined the theoretical inventory management problems expected in implementing the Hazardous Material Minimization Concept at FISC Puget Sound. Actual operating data must be obtained to test the forecasting and inventory modeling techniques suggested in this thesis.

Immediate future research should involve a pilot study involving one or two customers having the most complete demand data in an effort to begin testing and refinement of the forecasting and inventory modeling techniques. The most likely candidates seem to be either Puget Sound Naval Shipyard or the Trident Refit Facility.

APPENDIX A. SAMPLE HICS DATA FILES

This appendix contains sample data from the HICS files from NAWS Point Mugu.

A. ISSUE.DBF

A sample of the ISSUE.DBF is shown in Table A-1(a). Because of the number of data columns the file has been reproduced on separate lines to fit on the page and several column headings are truncated. An explanation of each data column is found in Table A-1(b) [Ref.23:App.D].

CTRL_NO	TRANS_NO	REC_CODE	BARCODE	CAGE	PARTNO	QTY	ISS_UNIT	U_PRICE
94000029	01	P776	8040002738717			1	PT	3 18
94000031	01	P776	8030008505717		PR 1422 (A 1/2	1	QT KT	0 00
94000032	01	VXE-6	9150009857099			72	QT	3 94
94000033	01	P7722	8030010411596		MIL-C-85054A	1	PT	0 00
94000033	02	VXE-6	8030005468637		MIL-C-81309D	6	16OZ	4 47
94000033	03	P779	8010006169181			1		0 00
94000035	01	GTSI P3	7930LLL059004		MA102	3	5 GL	74 00
94000036	01	VXE-6	9150009857099			48	QT	3 94

CTRL_NO	T_PRICE	ISS_DATE	LOCATION	UPD_DATE	REQ_NAME	ISS_TIME	CA_ITEM	TOT_CHA
94000029	3 18	10/2/93	553	10/2/93	MAUCH	08 54 40	N	3 18
94000031	0 00	10/2/93	553	10/2/93	MAUCH	09 06 14	Y	0 00
94000032	283 68	10/2/93	343	10/2/93	HENASEE	09 22 06	N	283 68
94000033	0 00	10/2/93	325	10/2/93	ALEXANDER	09 34 05	Y	0 00
94000033	4 47	10/2/93	325	10/2/93	ALEXANDER	09 34 05	Y	0 00
94000033	0 00	10/2/93	325	10/2/93	ALEXANDER	09 34 05	N	0 00
94000035	222 00	10/4/93	349 X6354	11/2/93	BABB	07 14 10	N	222 00
94000036	189 12	10/4/93	34 X7320	10/4/93	WALSH	07 41 19	N	189 12

CTRL_NO	NOMEN	POCCODE	OUTWEIGH	INWEIGHT	NETWEIGH	OUTVOL	INVOL
94000029	ADHESIVE (MONKEY SNOT)		0 00000	0 00000	0 00000	0 00000	0 00000
94000031	SEALING CMPD PR 1422 (A		0 00000	0 00000	0 00000	0 00000	0 00000
94000032	LUB OIL A/C ENG TURBO SYN		32 00000	4 50000	27 50000	0 00000	0 00000
94000033	CORR PREV COMP (TY1)		0 00000	0 00000	0 00000	0 00000	0 00000
94000033	CORR PREV COMP (TY3/CL2)		0 00000	0 00000	0 00000	0 00000	0 00000
94000033	PAINT PRIMER AERO LIGHT G		8 00000	0 00000	8 00000	0 00000	0 00000
94000035	CLNG CMPD A/C MA-102 (TY	MIL-999-99	0 00000	0 00000	0 00000	0 00000	0 00000
94000036	LUB OIL A/C ENG TURBO SYN	MIL-999-99	11 50000	0 00000	0 00000	0 00000	0 00000

CTRL_NO	NETVOL	WASTE_WT	WASTE_VL	CA_QTY	WASTE_QY	WAIVE_QY	WSTE_DT	JOWO	ISSUE_BY
94000029	0 00000	0 00000	0 00000	0	0	0			
94000031	0 00000	0 00000	0 00000	0	0	0			
94000032	0 00000	0 00000	0 00000	0	0	0			
94000033	0 00000	0 00000	0 00000	0	0	0			
94000033	0 00000	0 00000	0 00000	0	0	0			
94000033	0 00000	0 00000	0 00000	0	0	0			
94000035	0 00000	0 00000	0 00000	0	0	0			
94000036	0 00000	0 00000	0 00000	0	0	0			

Table A-1(a). Sample data from the ISSUE.DBF file.

ISSUE.DBF				
Issue Database, containing information about issues to customers.				
FIELD NAME	LONG NAME	DEFINITION	TYPE	SIZE
I_CTRL_NO	Control Number	System-assigned number identifying an order	CHAR	8
I_TRANS_NO	Transaction Number	Number assigned to each barcode item on order	CHAR	2
I_REC_CODE	Receiving Code	Code number of activity receiving material	CHAR	13
I_BARCODE	Barcode	13-digit number (same as NSN)	CHAR	13
I_CAGE	CAGE	Commercial and Government Entity No.	CHAR	5
I_PARTNO	Part Number	Manufacturer's part number	CHAR	20
I_QTY	Quantity	Amount of material being issued	NUM	5
I_ISS_UNIT	Unit of Issue	Unit of Issue of material	CHAR	5
I_U_PRICE	Unit Price	Price per U/I	NUM	7,2
I_T_PRICE	Total Price	Total price	NUM	9,2
I_ISS_DATE	Issue Date	Date material was issued	DATE	8
I_LOCATION	Location	Delivery location	CHAR	20
I_UPD_DATE	Date of Update	Date record was updated	DATE	8
I_REQ_NAME	Requestor	Name of person requesting material	CHAR	20
I_ISS_TIME	Issued Time	Time material was issued	CHAR	8
I_CA_ITEM	Cost Avoided Item	* indicates Cost Avoided material	CHAR	1
I_TOT_CHRG	Total Charge	Total Cost for all items	NUM	9,2
I_NOMEN	Nomenclature	Descriptive name of material	CHAR	25
I_POCCODE	Process Operation Code	Designates intended use of material	CHAR	14
I_OUTWEIGH	Issued Weight	Weight of material being issued	NUM	10,5
I_INWEIGHT	Returned Weight	Total weight of returned material	NUM	10,5
I_NETWEIGH	Net Weight	Diff. between Issued Weight and Returned Weight	NUM	10,5

Table A-1(b). Explanation of the data columns in the ISSUE.DBF file.

ISSUE.DBF				
Issue Database, containing information about issues to customers.				
FIELD NAME	**LONG NAME**	**DEFINITION**	**TYPE**	**SIZE**
I_OUTVOLUM	Issued Volume	Volume of material being issued	NUM	10,5
I_INVOLUME	Returned Volume	Total volume of returned material	NUM	10,5
I_NETVOLUM	Net Volume	Diff. between Issued Volume and Returned Volume	NUM	10,5
I_WASTE_WT	Waste Weight	Weight of material returned as Waste	NUM	10,5
I_WASTE_VL	Waste Volume	Volume of material returned as Waste	NUM	10,5
I_CA_QTY	Cost Avoided Quantity	Amount of issued quantity returned and re-entered into inventory as Cost Avoided material	NUM	5
I_WASTE_QY	Waste Quantity	Amount of issued quantity returned as Waste	NUM	5
I_WAIVE_QY	Waive Quantity	Amount of issued quantity that will not be returned	NUM	5
I_WASTE_DT	Waste Date	Date unused or waste quantity was returned	DATE	8
I_JOWO	Job/Work Order	Job Order or Work Order number	CHAR	10
I_ISSUE_BY	Issued By	Name of person performing Issue	CHAR	10

Table A-1(b). Continued.

B. ORDER.DBF

A sample of the ORDER.DBF file is shown in Table A-2(a). An explanation of each data column is found in Table A-2(b) [Ref.23:App.D].

O DOC NO	O BARCODE	O NOMEN	O UI	O QTY ORD	O DATE ORD	O QTY REC	O DATE REC	O STATUS	O 1348
3056-HVVG	8030011432702	TORQUE SEAL	TU	12	5/3/93	12	5/3/93	C	TRUE
3105-HUVG	6850002097231	CORR PREV COMP MIL-C-8188C	GL	6	5/4/93	6	5/4/93	C	TRUE
3117-HPVG	6850002745421	SOLVENT KWIK DRY (PD-680 II)	CN	5	5/4/93	5	5/4/93	C	TRUE
3007-HJVG	6850010115669	CALIBRATING FLUID	GL	24	5/4/93	24	5/4/93	C	TRUE
3124-HNVG	8010013138700	PAINT EPOXY WHITE 17925	KT	10	5/4/93	10	5/4/93	C	TRUE
3106-HBVG	8110008238121	DRUM 55 GL OPEN TOP	EA	30	5/4/93	30	5/4/93	C	TRUE
3014-HLVG	9150011313325	HYD FLUID MIL-H-46170B TY2 CN	CN	18	5/4/93	18	5/4/93	C	TRUE
3022-HSVG	BELZONA4111MA	BELZONA MAGMA ATZ IND 4111	KT	9	5/4/93	9	5/4/93	C	TRUE
3125-HXVG	6810002388119	NAPTHA ALPHATIC	GL	6	5/5/93	6	5/6/93	C	TRUE
3105-HSVG	6810006640387	TRICH 1 1 1 O-T-620C	GL	24	5/5/93	24	5/18/93	C	TRUE
3105-HTVG	6820009268867	DYE LIQUID RED MIL-D-81298CTY1	BT	6	5/5/93	6	7/26/93	C	TRUE
3125-HWVG	6850002248353	METHANOL TECH	55GL	4	5/5/93	4	5/11/93	C	TRUE
3109-HJVG	8010013137283	PAINT EPOXY RED 11136	KT	10	5/5/93	10	6/10/93	C	TRUE
3077-HOVG	8010013137288	PAINT EPOXY ORANGE 12197	KT	10	5/5/93	10	5/18/93	C	TRUE
3095-HPVG	8010013137292	PAINT EPOXY YELLOW 13538	KT	6	5/5/93	0	11/11/11	O	TRUE
3105-HWVG	8010013142524	PAINT EPOXY BLUE 15044 INSIGN	KT	10	5/5/93	10	5/19/93	C	TRUE
3125-HQVG	8010013163034	PAINT EPOXY GREY 36320	KT	10	5/5/93	10	7/26/93	C	TRUE
3125-HRVG	8010013163039	PAINT EPOXY GREY 36375	KT	12	5/5/93	12	5/5/93	C	TRUE
3081-HBVG	8030000087198	SEALING CMPD 81733	KT	6	5/5/93	6	7/8/93	C	TRUE
3081-HCVG	8030006020045	SEALING CMPD MIL-S-8343A B1/2	CA	24	5/5/93	24	8/19/93	C	TRUE
3117-HQVG	8040009023871	ADHESIVE 46106A TP 1 RED	KT	6	5/5/93	6	5/5/93	C	TRUE
3123-HIVG	8040011680077	ADHESIVE RTV 133 BLACK	CA	12	5/5/93	12	7/19/93	C	TRUE
3123-HFVG	9150001497432	HYD FLUID MIL-H-83282C GL	GL	90	5/5/93	90	5/6/93	C	TRUE
3123-HJVG	9150004580075	LUB OIL VV-L-800 AEROSOL	CN	48	5/5/93	48	5/6/93	C	TRUE
3123-HGVG	9150009857099	LUB OIL A/C MIL-L-23699C QT	QT	288	5/5/93	288	5/6/93	C	TRUE

Table A-2(a). Sample data from the ORDER.DBF file.

ORDER.DBF Order Database, used when material is ordered on a pick ticket or Form 1348.				
FIELD NAME	LONG NAME	DEFINITION	TYPE	SIZE
O_DOC_NO	Document Number	System-assigned number	CHAR	9
O_BARCODE	Barcode	13-digit number (same as NSN)	CHAR	13
O_NOMEN	Nomenclature	Descriptive name of material	CHAR	30
O_UI	Unit of Issue	Unit of issue of material	CHAR	5
O_QTY_ORD	Quantity Ordered	Amount of material ordered	NUM	5
O_DATE_ORD	Date Ordered	Date order was placed	DATE	8
O_QTY_REC	Quantity Received	Amount of material received	NUM	5
O_DATE_REC	Date Received	Date order was received	DATE	8
O_STATUS	Status	Status of order within HICS	CHAR	1
O_SUP_STAT	Supply Status	Status of order within Supply System	CHAR	2
O_1348	1348 Flag	Flag indicating order placed on 1348	LOG	1

Table A-2(b). Explanation of the data columns in the ORDER.DBF file.

APPENDIX B. NAVSUPINST 4200.85A

NAVSUPINST 4200.85A

Subj: HAZARDOUS MATERIAL

General Rule:

Procurement of hazardous material is not generally authorized unless approval has first been obtained from a designated Navy Hazardous Material minimization control Program Office. Most Navy activities have such responsible personnel assigned. The Commanding Officer is authorized to approve procurement of hazardous material for the Navy Afloat community.

OPNAVINST 5100.23B (Ashore) provides that the requisitioner is responsible for advising the Contracting officer that the contract will involve deliverables containing hazardous material.

OPNAVINST 5100.19B (Afloat) requires that hazardous material not appearing on the SHML, COSAL, SPMIG, the Navy Ships Technical Manual, or other Navy directives or official publication, SHALL NOT BE ORDERED, unless specifically authorized by the Commanding Officer. The required certification must accompany the requisition to the procurement activity. THE AUTHORIZATION MAY NOT BE DELEGATED BELOW THE COMMANDING OFFICER.

Identification of Hazardous Material is a function of the Technical Screening Process. FED-STD-313C provides identification of hazardous items by Federal Supply Class and requires an MSDS be submitted for all items listed in Table I (FSC 6810, 6830, 7930, 8010, 8040, 9110, etc.) and for items listed in Table II if the items have one or more of the characteristics of a hazardous material (e.g., asbestos, mercury, polychlorinated biphenyls flash point below 200 degrees F, produces fumes, vapors, mists or smokes during normal operation, flammable solid, radioactive, formaldehyde, classified as hazardous, etc.). Technical Screeners shall clearly indicate on the requisition that the item being ordered is hazardous (e.g., affix hazard warning label, hazardous stamp, etc.).

Under DFARS 223.300, DOD has granted itself a deviation from FAR 23.3. DOD agencies shall follow policies and procedures set forth in DFARS 223.72 rather than the coverage in FAR 23.3. When acquiring hazardous materials, the Contracting officer shall include the clause at DFARS 252.223-7004 "Hazardous Material Identification and Material Safety Data" (Jul 1989), rather than FAR 52.223-3. The DFARS clause requires the offeror to certify that the material is/is not hazardous. The offeror further agrees to submit prior to award an MSDS meeting the requirements of 29 CFR 1910.1200(g). Failure to comply with this requirement shall result-in the Offerer's being considered nonresponsible and ineligible for award.

DODINST 6050.5 requires that the Contracting officer is responsible for forwarding the MSDS and a copy of the manufacturers compliant hazard warning label to the DOD Components' HMIS focal point Naval Environmental Health Center (NEHC).

In addition, contracting activities shall reference FED-STD-313C (Mar 1988), or the edition in effect on date of issuance, in commodity specifications, contracts, and purchase documents for hazardous materials to assure inclusion of adequate requirements and clear instructions to contractors for the preparation and submission of the Material Safety Data Sheet (MSDS). For each hazardous item procured, the contractor shall be required to complete an MSDS and provide it to the procuring activity as part of the contract. FED-STD-313C requires that in addition to any other MSDS requirements in the contract, contractors also shall submit one copy of each MSDS to:

Navy Environmental Health Center
Attn: HMIS Code 341
2510 Walmer Avenue
Norfolk, Va. 23513-2617

Exceptions:	None.
References	29 CFR 1910.1200(g) FED-STD-313C DODINST 6050.5 OPNAVINST 4110.2 OPNAVINST 5100.19B OPNAVINST 5100.23B DFARS 223.300 DFARS 223.72

APPENDIX C. HAZARDOUS WASTE DISPOSAL RATES AT FISC, PUGET SOUND

GUIDE FOR USING HAZARDOUS WASTE PROCESS SHOP RATES

1. *WHEN TO USE THE RATES*

a. The Process Shop disposal rates are to be included in funding estimates and charging for work processes, contracts or projects involving the generation of hazardous waste on Shipyard property. The rates are applicable to Ships, Tenants, Contractors, Shops, Codes and any other entity generating waste on Shipyard property. There are some facility contractor exceptions which are evaluated on a case by case basis. Contact Teri Bailey in Code 952.4 at 6-0663 for questions on exceptions.

b. The rates also apply for non-hazardous wastes which cannot be disposed in the trash or in the sewer. A waste stream number has been established for processes which generate waste, both hazardous and non-hazardous, if it has been identified to Code 952.4. The waste streams are listed in the Waste Stream Dictionary published by Code 952.4 along with the proper method of disposal of the waste. Section 4 of this guide describes the proper method for determining which rate is to be used, if any for the wastes involved in your process/project.

2. *WHAT THE RATE INCLUDES*

a. The Process Shop part of the rate covers all direct work involved with disposal of the waste (this includes storing, sampling, consolidating or repacking, identification, manifesting, shipping, certificate tracking, etc.), material costs such as drums, labels, etc., the transportation cost charged to the Shipyard by the disposal contractor, and overhead functions related to disposal of hazardous waste. These costs are included in the above rates and should not be estimated separately.

3. *WHAT THE RATE DOES NOT INCLUDE*

a. When hazardous waste is generated the originator (person accomplishing the process which generates the waste) must ensure the waste is in a proper container which does not leak. The originator must label the container to show what the waste is. The originator's name and phone number must also be written on the label so that they may be contacted if further information is required. The originator must also make arrangements to have the waste removed from the job site. This is done by completing a Waste Information Sheet and contacting Shop 02 at 6-7777. These are the minimum requirements of the waste originator and are considered part of the process which generated the waste. These actions are to be funded by the same document which funded the accomplishment of the job and are not part of the Process Shop rate.

Enclosure (2)
Page 1

GUIDE FOR USING HAZARDOUS WASTE PROCESS SHOP RATES

4. *WHICH RATE TO USE*

a. In order to determine which disposal rate on the matrix is applicable to the waste created by your process/project the estimator must know what type of waste will be made, how it will be disposed, how it will be packaged for disposal and whether the project is direct or indirect funded. For existing process wastes the rates have already been established and are programmed automatically into the billing report sent to Code 610 from S/02.

b. HAZARDOUS VERSUS NON-HAZARDOUS

The rates are set up for hazardous and non-hazardous solid and liquid waste streams and their corresponding disposal methods. In order to determine which rate is applicable you will need a general idea of what kind of wastes will be created and the processes that cause those wastes to be made. This will help you to look up the waste stream in the Waste Stream Dictionary. The Waste Stream Dictionary then lists the appropriate disposal method for the waste stream(s) involved. If you cannot find the waste in the Waste Stream Dictionary or need assistance contact a Code 952.4 representative at 6-8607.

It is possible that the waste in question has not been identified yet and will need to be reviewed by Code 952.4 for designation and to determine the appropriate disposal method. A Waste Information Sheet should be completed and any process documentation attached and forwarded to Code 952.4 for evaluation prior to making the waste in accordance with NAVSHIPYDPUGET INST P5090.5C. For estimating purposes rate M can be used for drummed waste which is pending designation. For bulk waste pending designation rates A3 and C can be used for solids and liquids respectively. (See section 4.c for bulk versus drum information.) Contact Code 952.4 to determine what the appropriate CLIN cost might be for estimating purposes for bulk waste. Code 952.4 will need to know what potential contaminants may be found in the waste. This can be determined from process knowledge or sample data. Code 106.31 has data from soil drilling samples on contaminants in the various Installation-Restoration (IR) sites in the Shipyard.

c. BULK VERSUS DRUM:

When determining the rate the estimator must consider the amount of waste which will be generated in one batch or within a three day time period. A bulk rate may be used if the amount is so large that the waste cannot reasonably be put in 55 gallon drums. If the amount is small enough that it may be drummed the containerized rate should be used. Some small items which are consolidated into bulk shipping containers in a short time period may be charged the bulk rate depending on S/02 handling expenses. An example of this is the bagged PCB solid waste from the sub recycle projects which is consolidated into the large roll-off boxes for shipment.

The drum rate is applicable for all disposable containers which have a capacity of 110 gallons or less. This includes bags, 5 gallon cans, boxes, 80 gallon drums, etc. Note that the weight of the container is included in the disposal rate charged to the customer as the Process Shop pays the disposal contractor for the container weight likewise. A 55 gallon steel drum weighs approximately 40 pounds.

d. DIRECT VERSUS INDIRECT:

Waste disposal will be billed at a direct or indirect rate depending on the type of customer/project to which the waste is attributed. Ships, Tenants and Contracts are direct customers and waste generated by work for these projects will be billed at the direct rate. Work for Shops and Codes is indirect and customers pay the indirect rates. The difference between the direct and indirect rates is the G & A overhead fee and would be redundant if charged to Shops and Codes. This fee is calculated annually by Code 600 as a percentage of the actual labor involved with a service. At this time it is negligible for the bulk rates and is therefore not added.

5. This information is intended to assist personnel in estimating work which involves the generation and disposal of hazardous waste at Puget Sound Naval Shipyard. Questions can be directed to any of the Shop 02 Foremen at 6-6432 or to Teri Bailey in Code 952.4 at 6-0663.

Some large contracts (EFA, etc) Have not have to use PSNS disposal contractor — so will need J.O.# for direct charge — (Rate Z)

DISPOSAL RATE MATRIX FOR FY 95

RATE CODE	RATE CATEGORY DESCRIPTION	DIRECT RATE	INDIRECT RATE
A1	BULK HAZARDOUS SOIL OR GRIT SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.10 + CLIN	$0.10 + CLIN
A2	BULK HAZARDOUS PCB SOLIDS SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.27 + CLIN	$0.27 + CLIN
A3	BULK HAZARDOUS SOLIDS (OTHER THAN PCB OR SOIL) SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.18 + CLIN	$0.18 + CLIN
B1	BULK NON-HAZARDOUS SOLIDS SENT TO S/02 CONTRACTOR FOR DISPOSAL (All types but asbestos)	$0.18 + CLIN	$0.18 + CLIN
B2	BULK NON-HAZARDOUS ASBESTOS SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.64 + CLIN	$0.64 + CLIN
C	BULK HAZARDOUS LIQUIDS SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.25 + CLIN	$0.25 + CLIN
D	BULK NON-HAZARDOUS LIQUIDS SENT TO S/02 CONTRACTOR FOR DISPOSAL	$0.25 + CLIN	$0.25 + CLIN
E	BULK HAZ/NON-HAZ LIQUIDS SENT TO S/02 FOR ON-SITE TREATMENT	$0.03	$0.03
F	DRUMMED HAZARDOUS WASTE SENT TO S/02 CONTRACTOR FOR DISPOSAL	$1.76 + CLIN	$1.53 + CLIN
G	DRUMMED NON-HAZARDOUS WASTE SENT TO S/02 CONTRACTOR FOR DISPOSAL	$1.76 + CLIN	$1.53 + CLIN
H	DRUMMED NON-HAZARDOUS SOLIDS SENT TO TRASH VIA S/02 INSPECTION	$0.86	$0.63
I	DRUMMED NON-HAZARDOUS LIQUIDS SENT TO SEWER VIA S/02 INSPECTION	$0.86	$0.63
J	DRUMMED HAZ/NON-HAZ LIQUIDS SENT TO S/02 FOR ON-SITE TREATMENT	$0.86	$0.63
K	DRUMMED HAZ/NON-HAZ WASTE SENT TO S/02 FOR RECYCLE/REUSE	$0.86	$0.63
L	DRUMMED PROBLEM WASTE SENT TO S/02 FOR LANDFILL CERTIFICATION	$1.72	$1.49
M	DRUMMED WASTE PENDING DESIGNATION BY S/02	$3.13	$2.90

[CLIN = Contract Line Item Number in the Hazardous Waste Disposal Contract.]

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DW_EHW / NFPA	PPE	LABEL	[illegible]
*** WASTE ORIGINATED BY TA						
TA-120-0104	ACIDIC SOLUTIONS	HAZ, LABPACK PRIOR TO SHIPMENT	SEE NOTES	002	DB ,HW ,ID ,WC ,	10-3[illegible]
CLEANING AGENTS, ACIDIC	LIQUID/COLOR VARIES		E		WI	1.35
	EQUIP FLUSHING/RUST & SCALE REMOVAL/VARI	METAL DRUM W/PLASTIC LINER				

See Notes Information

OLD WASTE STREAM #'S:

1. (120-0004) CITRIC ACID SOLUTION, YELLOW LIQUID, LASER MACHINE FLUSH, MSDS #1045, LAB ANALYSIS #93PS07656, BULK ACID TANK #1.
2. (120-0005) ACID, CLEAR LIQUID, RUST REMOVER, NFPA #3-1-0-CORR/ACID, BULK ACID TANK, KEE AWAY FROM CORROSIVES.
3. (120-0020) USED #7 H.P. CLEANER & FLUSH WATER, THIN MILKY LIQUID, RADIATOR FLUSHING, RADIATOR CLEANER, PART #2131N, MFG: BORDEN INC., MSDS #5891, LAB ANALYSIS #91PS24012, NFPA 3-1-0-CORR/ACID.
4. (120-0060) CITRIC ACID CLEANING LIQUID, SPENT, BROWN LIQUID, CLEANING SHIPBOARD FRESH WATER SYSTEMS, TRADE NAME: CITRIC ACID & ANHYDROUS, NSN: 001412942, MFG: MILS LABORATORY INC., MSDS #1045, NFPA 3-0-0-ACID.
5. (120-0080) SULFURIC & NITRIC ACID SOLUTION, SPENT, CLOUDY LIQUID, BRIGHT DIP CLEANING IN TANK, TRADE NAME: BRIGHT DIP, NSN: 002499354, MFG: FISHER SCIENTIFIC, MSDS #4328, NFPA 3-0-0-ACID.
6. (120-0081) EXCESS SULFAMIC ACID SOLUTION, PURPLE COLOR, SUFAMIC ACID & WATER, CLEAN REFRIGERATION COILS, TRADE NAME: IMPERIAL SCALE REMOVER, MFG: NU-CALGEN WHOLESALE, MSDS #5770, NFPA 3-0-0-ACID.

SHOP AND NOTES CONTINUED ON PAGE: 2

Date: [illegible]

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DU_EHW / NFPA	PPE	LABEL	[illegible]

*** WASTE ORIGINATED BY TA

TA-120-0104 ACIDIC SOLUTIONS

7. (120-0086) PHOSPHORIC ACID/WATER MIXTURE, COLORLESS, TRANSPARENT LIQUID, CORROSION REMOVER, NSN: 006561291, PART #N00104-76-M-4878, MILSPEC: #MIL-C-10578, MFG: BARRETT CHEMICAL CO., NFPA 3-0-0-ACID.
8. (120-0087) SULFURIC ACID/THIOUREA MIXTURE, GREEN LIQUID, WINTERGREEN ODOR, CLEANING ELECTRONIC CONTACTS, TRADE NAME: E-Z-EST SPEEDIP, MSDS #1442, NFPA 3-0-0-ACID, SEPARATE FROM ALKALINES. STORE IN PLASTIC CONTAINERS.
9. (CHROMIC & SULFURIC ACID SOLUTION, SPENT, CLOUDY LIQUID, CHROME DIP CLEANING IN TANK, TRADE NAME: CHROME DIP SOLUTION, NSN: 002499354, MFG: FISHER SCIENTIFIC, MSDS #1763/513A-D, NFPA 3-0-1-ACID.
10. CLEANER DIP, LIGHT BROWN ACIDIC, PROCESS: DIPPING COMPRESSOR PARTS, MFG: HOCKING INTERNATIONAL, MSDS #2621.
11. CITRIC ACID & WATER, MSDS #1045.
12. SPEED DIP/WATER (SILVER CLEANER), LIQUID, MSDS: 5335, MFR: ELLANAR DIP 175, L&R MFG CO., LIGHT GREEN.
13. CLEANER - ACIDIC - MASONARY, EXCESS/UNWANTED, LIQUID/ACIDIC/CLEAR, TRADE NAME: SURE KLEEN VANN TROL, MSDS #3600, METHOD OF DISPOSAL (16).

TA-130-0101	CAUSTIC SLUDGE	HAZ, SHIPPED OFF-SITE FOR TRTMNT\DISP	SEE NOTES	004	D8 ,HW ,ID ,WT	1031AH
CLEANING AGENTS, ALKALINE	SLUDGE/BI-LAYERED, GREY & BROWN		E			1.35
	DIP TANK, LYE TANK, PARTS CLEANING	PLASTIC DRUM OR OPEN TOP W/LINER	3-0-1-ALK			

See Notes Information

OLD WASTE STREAM #'S:

SHOP AND NOTES CONTINUED ON PAGE: 3

120

Date: [illegible]

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DV_EHW / NFPA	PPE	LABEL	CLIN # / CLIN RATE

*** WASTE ORIGINATED BY TA

TA-130-0101 CAUSTIC SLUDGE
1. (130-0001) CAUSTIC SLUDGE, NSN #LLS042177, MFG: GENIUM PUBLISHING, MSDS #1044.
2. (130-0022) CUASTIC CLEANER (LYE), LIQUID, PARTS CLEANING.

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DV_EHW / NFPA	PPE	LABEL	CLIN # / CLIN RATE
TA-130-0102 CLEANING AGENTS, ALKALINE	ALKALINE MIXED LIQUID CLEANERS VARIOUS COLORED LIQUID PARTS/PIPES/COMPONENTS/ENG/BATTERY/GP DE	HAZ, SHIPPED OFF-SITE FOR TRTMNT\DISP PLASTIC CONTAINER	SEE NOTES E	004	DB ,HW ,IC ,WT	

See Notes Information
OLD WASTE STREAM #'S:
1. (130-0002) SODIUM HYDROXIDE SOLUTION, SPENT, SINGLE LAYER, CLEAR, CLEAN (DIESEL) GEN., ENGINE BEARINGS (DIESEL), TRADE NAME: CAUSTIC SODA, LYE, NSN: LLS042177, MSDS #1829, NFPA 3-0-1-ALK.
2. (130-0003) SODIUM HYDROXIDE SOLUTION,SPENT, BROWN LIQUID, PIPE/COMPONENT CLEANING (CAUSTIC) IN TANK, TRADE NAME: LYE, CAUSTIC, NSN: LLS042177, MFG: MILES LAB INC., MSDS #1044, NFPA 3-0-1-ALK.
3. (130-0004) MIXED ALKALINE LIQUID, GRAY/BROWN LIQUID, PROCESS: AQUEOUS DETERGENT PARTS WASHER, LAB ANALYSIS #92PS31637, NFPA 3-0-1-ALK.
4. (130-0005) ALKALINE CLEANER-SPENT, PHYSICAL: GREY LIQUID, PROCESS: FLOOR CLEANING, NFPA 2-0-0.
5. (130-0006) ZEP DETERGENT/H2O/OIL, PHYSICAL: BLACK LIQUID, PROCESS: AQUEOUS PARTS WASHER B/438, MSDS

SHOP AND NOTES CONTINUED ON PAGE: 4

WE110... Date: 10/2?/94

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DW_EHW / NFPA	PPE	LABEL	CLIN # / CLIN RATE

*** WASTE ORIGINATED BY TA

TA-130-0102 ALKALINE MIXED LIQUID CLEANERS
#6141, NFPA 2-0-0-ALK.
6. (130-0008) GLASS CLEANER LIQUID, TRADE NAME: GLASS CLEANER LIQUID, NSN #006646910, MSDS #4385, NFPA 2-0-0-ALK.
7. (130-0023) MIXED ALKALINE CLEANERS, GENERAL CLEANING, TRADE NAME: SAMURAI, NFPA 3-0-0-ALK.
8. (130-0071) NEW LAND SUPER CLEANER, DIRTY, DARK BROWN LIQUID, THIN, PROCESS: CLEANING COMMUNICATIONS EQUIPMENT, TRADE NAME: SUPER CLEANER, MFG: NEW LAD PROD INC., MSDS #512, NFPA 2-1-0.
9. (130-0080) CHEM-CREST 200, SPENT, LIQUID, FLUSH CLEANING PIPING, TRADE NAME: CHEM-CREST, NSN #00N028449, PART #200, MFG: CREST ULTRASONIC CO., MSDS #2470, NFPA 3-0-0-ALK.
10. (130-0090) BAKING SODA W/WATER, DIRTY, THIN BROWN LIQUID, PROCESS: CLEANING BATTERY BANKS AT SUBSTATIONS, NFPA 2-0-0.
11.(130-0102) GRILL & OVEN DEGREASER, USED PORTION IN DAMAGED CONTAINER, LIQUID-SLIGHT YELLOWISH-PH > 12.5, TRADE NAME: FAST CLEAN, STOCK #: 7930-010750776, 5/8/55 GAL OPEN TOP CONTAINER.
12. HEAVY DUTY INDUSTRIAL CLEANER, REDDISH/PINK LIQUID, pH 12.8 TO 13.

TA-130-0103	FLOOR WAX REMOVER	HAZ, SHIPPED OFF-SITE FOR TRTMNT\DISP	SEE NOTES	003	DB ,HW ,ID ,WT	
CLEANING AGENTS, ALKALINE	LIQUID					
	CLEANING FLOORS	PLASTIC	2-1-0-ALK			

See Notes Information
OLD WASTE STREAM #
SHOP AND NOTES CONTINUED ON PAGE: 5

Date: 10/21/94

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DU_EHW / NFPA	PPE	LABEL	CLIN # / CLIN RATE

*** WASTE ORIGINATED BY TA .

TA-130-0103 FLOOR WAX REMOVER
1. (130-0009) FLOOR WAX REMOVER, LIQUID, EXCESS, MILSPEC: A-A-861, MSDS #5160/2031.

TA-140-0106 CHEMICAL PAINT STRIPPING	PAINT STRIPPER & SPRAY GUN CLEANER CLEAR LIQUID UNUSED/EXCESS/LEFTOVER	HAZ, LABPACK PRIOR TO SHIPMENT 5,8,55 GAL OPEN TOP	NA E	005	D3 ,HW ,ID ,WC , WT	10-3AC 1.35

See Notes Information
OLD WASTE STREAM #'S:
1. (140-0008) Z-STRIP, CLEAR LIQUID, PROCESS: CHEMICAL PAINT REOVER, MFG: INLAND TECHNOLOGY.
2. (140-0012) SPRAY GUN CLEANER, LIQUID/WHITE AROMATIC & CHLORINATED ODOR, PROCESS: LEFT OVER PRODUCT-USED FOR PAINT STRIPPING, TRADE NAME: X-6030, MSDS #893.

TA-160-0108 SOLVENTS/SOLVENT CLEANING	PD 680 TYPE II, SOLVENT, DIRTY CLEAR -> DARK -> THICK LIQUID DRMO REJECT, PARTS CLEANING & EQUIP/ W/O	HAZ, SHIPPED OFF-SITE FOR TRTMNT\DISP	NA E	006	HW ,ID ,LD ,WC	1035 0.82

See Notes Information
WASTE STREAMS PREVIOUSLY USED:
1. (160-0020) PD 680 & GP GREASE, TRADE NAME: DRY CLEANING SOLVENT, NSN: 002745421, MILSPEC: MIL-C-1889, MSDS: 2473, 2128A, NFPA: 2-2-0.
2. (160-0021) PD 690 TYPE II SOLVENT, UNUSED, TRADE NAME: DRY CLEANING SOLVENT, NSN: 001104498, MSDS:
SHOP AND NOTES CONTINUED ON PAGE: 6

WASTE STREAM # / WASTE TYPE	WASTE STREAM NAME / PHYSICAL DESCRIPTION / PROCESS DESCRIPTION	DISPOSAL METHOD / COMPATIBILITY REQUIREMENTS / SPEC. CONTAINER REQUIREMENTS	MSDS / DW_EHW / NFPA	PPE	LABEL	[illegible]

*** WASTE ORIGINATED BY TA

TA-160-0108 PD 680 TYPE II, SOLVENT, DIRTY
2128A, 2473, NFPA: 2-2-0.
3. (160-0022) PD 680 TYPE II, DIRTY, TRADE NAME: 140 SOLVENT-66, NSN: 002745421, MILSPEC: MIL-C-1889, MSDS: 2473, NFPA: 2-2-0.
4. (160-0023) PD 680 TYPE II SLUDGE, TRADE NAME: DRY CLEANING SOLVENT, NSN: 002745421, MILSPEC: PD680AMEND2, MSDS: 2128A, 2473, NFPA: 1-2-0.
5. (160-0025) PD 680 TYPE II SOLVENT, SPENT, TRADE NAME: DRY CLEANING SOLVENT, NSN: 002745421, MSDS: 2128, NFPA: 2-2-0.
6. PD 680 & SLUDGE WASTE, LIQUID/DARK BROWN TO BLACK, DISTILLING PD 680.

TA-160-0110	GUNK MOTOR FLUSH - MF-2	HAZ, LABPACK PRIOR TO SHIPMENT	NA	006	D3 ,HW ,ID [illegible]	[illegible]
SOLVENTS/SOLVENT CLEANING	AMBERISH LIQUID		E		W1	[illegible]
	LEAKING CANS					

See Notes Information
WASTE STREAMS PREVIOUSLY USED:
1. (160-0027) GUNK MOTOR FLUSH (MF-2), TRADE NAME: MF-2 MOTOR FLUSH, MFG: RADIATOR SPECIALTY.

TA-160-0112	ISOPROPYL ALCOHOL, USED-DIRTY	HAZ, SHIPPED OFF-SITE FOR TRTMNT\DISP	935A,935,VA	006	D3 ,HW ,ID ,W1	1035
SOLVENTS/SOLVENT CLEANING	CLEAR -> BROWN LIQUID W/OIL, DEBRIS		E			[illegible]
	CLEANING (PARTS) (NUC PARTS) (ELECTRONIC					

See Notes Information
WASTE STREAMS PREVIOUSLY USED:

SHOP AND NOTES CONTINUED ON PAGE: 7

APPENDIX D. SAMPLE ENVIRONMENTAL PERMIT TO OPERATE

Ventura County
Air Pollution
Control District

702 County Square Drive
Ventura, California 93003

tel 805/645-1400
fax 805/645-1444

Richard H. Baldwin
Air Pollution Control Officer

PERMIT TO OPERATE

Number 0997

Valid October 1, 1994 to September 30, 1995

This Permit Has Been Issued To The Following:

Company Name / Address:	Facility Name / Address:
Naval Air Weapons Station Code P732 Trailer 10073 Point Mugu, CA 93042	U.S. Navy-Air Weapons Center Surface Coating Operations Point Mugu, CA 93042-5002

Permission Is Hereby Granted To Operate The Following:

1 - Motor Vehicle and Mobile Equipment Coating Operations, with one Paint Spray Booth, 14 ft. x 26 ft. x 9 ft., with Overspray Filters, (Building 2-8)
1 - Aerospace Components Surface Coating Operations, (Building 34)
1 - Metal Parts and Products Surface Coating Operations, with one DeVilbiss Waterwash Paint Spray Booth, 18 ft. x 18 ft. x 10 ft, (Building 67)
1 - Grieve-Henry Electric Motor Burnout Oven, Model SP-6, 5 ft. x 6 ft. x 4 ft., natural gas fired, 4.50 MMBtu/Hr, processing 1.2 motors per hour, (Building 67)
1 - Trent Bake Oven, 8 ft. x 8 ft. x 8 ft., (Building 67)
1 - Metal Parts and Products Surface Coating Operations, with one Paint Spray Room, 60 ft. x 30 ft. x 30 ft., with three Water Curtains, (Building 311)
1 - Aerospace Components Surface Coating Operations, with one Paint Spray Booth, 6 ft. x 5 ft. x 4 ft., with Overspray Filters, 1,500 CFM, (Building 311)
1 - Abrasive Blast Room, 25 ft. x 18 ft. x 17 ft., with Cyclone Collector, (Building 311)
1 - Abrasive Blast Cabinet, Zero Blast-N-Peen, Model BNP 210-4, Serial Number 29106, (Building 311)
1 - ICM Superhone Abrasive Blast Cabinet, 7 ft. x 5 ft. x 4 ft., with Baghouse, (Building 311)
1 - Self Contained Abrasive Blast Cabinet, 3 ft. x 3 ft. x 6 ft., (Building 311)
1 - Motor Vehicle and Mobile Equipment Coating Operations, Metal Parts and Products Surface Coating Operations, and Aerospace Components Surface Coating Operations, with a Paint Spray Booth, 16 ft. x 48 ft. x 16 ft., with Overspray Filters, 12,600 CFM, (Building 319)
1 - Aerospace Components Surface Coating Operations, (Building 323)
1 - Aerospace Components Surface Coating Operations, (Building 324)
1 - Aerospace Components Surface Coating Operations, (Building 330)
1 - Aerospace Components Surface Coating Operations, (Buildings 349 and 351)
1 - Motor Vehicle and Mobile Equipment Coating Operations, Metal Parts and Products Surface Coating Operations, and Aerospace Components Surface Coating Operations, with a Paint Spray Booth, 24 ft. x 26ft. x 9 ft., with Overspray Filters, 12,600 CFM, (Building 354)
1 - Aerospace Components Surface Coating Operations, with one Paint Spray Booth, 10 ft. x 3 ft. x 7 ft., with Overspray Filters, 12,000 CFM,

09-26-94

VCAPCD Permit to Operate Number 0997
Issued To U.S. Navy-Air Weapons Center
Valid October 1, 1994 to September 30, 1995

(Buildings 364 and 365)
1 - Aerospace Components Surface Coating Operations, (Building 372)
1 - Aerospace Components Surface Coating Operations, (Building 553)
1 - Aerospace Components Surface Coating Operations, with one Paint Spray Booth, 18 ft. x 30 ft. x 15 ft., Waterwall, (Building 3012)
1 - ICM Superhone Abrasive Blast Cabinet, (Building 3012)
1 - Zero Blast-N-Peen Abrasive Blast Cabinet, (Building 3012)
1 - Aerospace Components Surface Coating Operations, (VXE-6 Squadron Corrosion Control Shop)
Architectural Coating Operations

This Permit Has Been Issued Subject To The Following Conditions:

1. Permitted Emissions:

Permitted Emissions:	Tons/Year	Pounds/Hour
Reactive Organic Compounds	14.96	15.15
Nitrogen Oxides	0.65	0.83
Particulate Matter	1.35	2.28
Sulfur Oxides	0.05	0.07
Carbon Monoxide	1.38	1.77
1,1,1-Trichloroethane	0.14	0.14
Methylene Chloride	0.28	0.28

2. Annual usage of the following materials shall not exceed the following:

   1) Aerospace Coating & Cleaning Operations: 360 gallons of topcoats with maximum ROC (reactive organic compounds) content of 3.5 pounds per gallon, and 3.5 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 108 gallons of primers with maximum ROC content of 2.92 pounds per gallon, and 2.92 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 100 gallons of specialty coatings with maximum ROC content of 7.72 pounds per gallon, and 7.72 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 300 gallons of ROC solvents with maximum ROC content of 7.40 pounds per gallon; 55 gallons of methylene chloride stripper containing no more than 10% by weight ROC additives; 30 gallons of 1,1,1-trichloroethane with no more than 1.67 pounds per gallon ROC content; and 2335 gallons of ROC solvents with maximum ROC content of 1.67 pounds per gallon.

   2) Metal Pamme-and Products Operations: 616 gallons of coatings with maximum ROC content of 2.8 pounds per gallon, and 2.8 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 50 gallons of ROC solvents with maximum ROC content of 7.40 pounds per gallon; and 146 gallons of solvents with maximum ROC content of 0.58 pounds per gallon.

   3) Automotive Coating Operations: 140 gallons of coatings with maximum ROC content of 6.0 pounds per gallon, and 5.0 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 400 gallons of coatings with maximum ROC content of 3.5 pounds per gallon, and 3.6 pounds per gallon on a minus water, minus exempt solvent basis, as

09-26-94

applied; 400 gallons of coatings with maximum ROC content of 2.80 pounds per gallon, and 2.8 pounds per gallon on a minus water, minus exempt solvent basis, as applied; 68 gallons of ROC solvents with maximum ROC content of 7.40 pounds per gallon; and 112 gallons of ROC solvents with maximum ROC content of 1.67 pounds per gallon.

4) Grieve-Henry Oven: 1,560 hours of operation per year.

5) Architectural Coating Operations: 1,864 gallons per year of coatings with maximum ROC content of 3.5 pounds per gallon, and 1,000 gallons per year of ROC solvents with maximum ROC content of 7.40 pounds per gallon.

6) Abrasive Blast Room - Building 311: 10 tons per year copper slag.

7) ICM Abrasive Blast Cabinet - Building 311: 0.25 tons per year aluminum oxide.

8) Self Contained Abrasive Blast Cabinet - Building 311: 0.25 tons per year aluminum oxide .

9) Abrasive Blast Cabinet, Zero Blast-N-Peen - Building 311: 0.25 tons per year aluminum oxide or glass beads.

10) ICM Superhorne Abrasive Blast Cabinet - Building 3012: 2.55 tons per year of copper slag.

11) Zero Blast-N-Peen - Building 3012: 3.10 tons per year of copper slag.

In order to comply with this condition, permittee shall maintain daily records and monthly reports as required by Condition Nos. 8, 9, 10, 16 and 17. The monthly totals shall be summed for the previous twelve (12) months. Material usage totals for the previous twelve (12) months in excess of the above limits shall be considered a violation of this condition.

Before exceeding any of the above limits, permittee shall submit an application to modify this condition.

3. This condition applies to the surface coating, cleaning, stripping, and the clean-up of equipment associated with aerospace components. The aerospace surface coating operations shall comply with all applicable provisions of APCD Rule 74.13. Permittee shall not use any solvent for surface cleaning unless the solvent contains less than 200 grams per liter of material, as applied, or the composite vapor pressure of the solvent is less than 25 mm Hg at 20 degrees Celsius. Permittee shall not use materials containing ROC for the cleaning of equipment used in coating operations unless an enclosed system or enclosed gun washer is used according to the manufacturer's recommendations and is closed when not in use. Permittee shall not use a coating stripper unless it contains less than 300 grams of ROC per liter, as applied.

09-26-94

4. This condition applies to the surface coating of metal parts and products. The Metal Parts and Products Surface Coating Operations shall comply with all applicable provisions of APCD Rule 74.12. Permittee shall not use any solvent for surface cleaning unless the solvent contains no more than 70 grams per liter of material, as applied. Permittee shall not use materials containing ROC for the cleaning of equipment used in coating operations unless an enclosed system or enclosed gun washer is used according to the manufacturer's recommendations and is closed when not in use, and the composite vapor pressure of organic compounds used is less than 45 mm Hg at a temperature of 20 degrees Celsius.

5. The Architectural Coating Operations shall comply with all applicable provisions of APCD Rule 74.2.

6. This condition applies to the motor vehicle and mobile equipment coating operations. The surface coating of motor vehicles and mobile equipment shall comply with all applicable provisions of APCD Rule 74.18. Permittee shall not use any solvent for surface cleaning unless the solvent contains no more than 200 grams per liter of material, as applied. Permittee shall not use materials containing ROC for the cleaning of equipment used in coating operations unless an enclosed system or enclosed gun washer is used according to the manufacturer's recommendations and is closed when not in use, and the composite vapor pressure of organic compounds used is less than 45 mm Hg at a temperature of 20 degrees Celsius.

7. This condition applies to the surface coating of metal parts and products; the surface coating of aerospace components; and the surface coating of motor vehicles and mobile equipment coating operations. All coatings shall be applied through proper use of the following:

   a) High Volume Low Pressure (HVLP) application; or
   b) Electrostatic application; or
   c) Hand application methods; or
   d) Dip or flow coating application; or
   e) Any other method which has been demonstrated to be capable of achieving at least 65 percent transfer efficiency.

8. For each Aerospace Assembly and Component Manufacturing Operation, and for each Metal Parts and Products Surface Coating Operation, permittee shall have the coating manufacturer's specification sheets available for review and shall maintain records which show on a daily basis, the type of coating; the grams of ROC per liter of coating, less water and less exempt solvent, as applied; the volume of each coating applied; the method of application; the type of solvent and stripper used, the ROC content of the solvent and the stripper, the volume and composite vapor pressure of the solvent.

9. For the Automotive Coating Operation, permittee shall maintain daily records which show the type of coating used, the grams of ROC per liter of coating, less water and less exempt solvent, as applied; the volume of each coating used; the type of vehicles coated; the identification of each solvent used and its use; the ROC content of solvent used; and the volume of solvent used.

10. For the Architectural Coatings Operation, permittee shall maintain records which show the type of coating used, the grams of ROC per liter of coating, less water and less exempt solvent, as applied; the volume of each coating used; the identification of each solvent used and its use; the ROC content of solvent used; and the volume of solvent used.

11. The paint spray booths shall not be operated without overspray filters or waterwalls. The filters shall be replaced before the spray booth manometer reaches 0.5 inches of water column.

12. All solvent containing materials, used or unused, including but not limited to surface coatings, surface preparation material and clean-up solvent shall be stored in closed containers.

13. All abrasive blasting activities shall be conducted in conformance with all applicable provisions of Title 17, California Administrative Code, Subchapter 6 (Abrasive Blasting) and District Rule 74.1 (Abrasive Blasting).

14. The discharge into the atmosphere from abrasive blasting operations conducted within a permanent building shall not be as dark or darker in shade than No. 1 on the Ringlemann Chart or of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described as Ringlemann No. 1. (Note: Ringlemann No. 1 is equivalent to 20% opacity), as required by APCD Rule 74.1.C.1.b.

15. The permittee shall employ reasonable methods to insure that discharge from the abrasive blasting work area does not cause a nuisance, pursuant to California Health & Safety Code Section 41700 and APCD Rule 51 (Nuisance). Such methods may include, but are not limited to, use of shrouding and covering of objects adjacent to the blasting activity.

16. Permittee shall maintain records showing the amount and type of abrasives used, and the hours of operation of the Grieve-Henry oven.

17. All records shall be compiled into a monthly report. Records shall be maintained for at least two years and shall be made available to APCD personnel upon request.

Within ten days after receipt of this permit, the applicant may petition the Hearing Board to review any new or modified condition on the permit (Rule 22).

This permit, or a copy, shall be posted reasonably close to the subject equipment and shall be readily accessible to inspection personnel (Rule 19). This permit is not transferable from one location to another unless the equipment is specifically listed as being portable (Rule 20).

In reliance upon the statement of the applicant that operation of the equipment described herein shall meet the requirements as specified in the Rules and Regulations of the Air Pollution Control District, permission is hereby granted to operate; provided, however, the permission granted hereby shall not be

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