1994-12

A demand forecasting model for a naval aviation intermediate level inventory -- the Shorebased Consolidated Allowance List (SHORCAL), Yokosuka, Japan

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MONTEREY, CALIFORNIA

THESIS

A DEMAND FORECASTING MODEL FOR A NAVAL AVIATION INTERMEDIATE LEVEL INVENTORY -- THE SHOREBASED CONSOLIDATED ALLOWANCE LIST (SHORCAL), YOKOSUKA, JAPAN

by

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December, 1994

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 1994	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE A DEMAND FORECASTING MODEL FOR A NAVAL AVIATION INTERMEDIATE LEVEL INVENTORY--THE SHOREBASED CONSOLIDATED ALLOWANCE LIST (SHORCAL), YOKOSUKA, JAPAN	5. FUNDING NUMBERS
6. AUTHOR(S) Randal J. Onders	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS NAVAL AVIATION INVENTORY; DEMAND FORECASTING; INTERMEDIATE LEVEL INVENTORY	15. NUMBER OF PAGES 107
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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Availability Codes		
Dist	Avail and / or Special	
A-1		

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1994

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ABSTRACT

Recent initiatives associated with the military force drawdown and declining Department of Defense budget mandate reducing military investment in spare parts inventories while maintaining force readiness. It is therefore important in the present environment to improve demand forecasting accuracy in order to meet supply performance goals. This thesis examines a naval aviation intermediate level inventory, the Shorebased Consolidated Allowance List (SHORCAL), Yokosuka, Japan. The primary focus is to develop an alternate demand forecasting model for the Yokosuka SHORCAL. The present forecasting model averages demand for an item over a twelve month period to determine its forecast. The alternate model consists of two sections. The first section is a causal model for forecasting demand originating from aircraft carriers. Flying hours and carrier deployment are used as independent variables. The second section uses a time-series and a marginal value method to forecast causal residuals and non-carrier demand. The two sections are then combined into a final forecast for an item. Demand history for seven Aviation Depot Level Repairables is used to develop the model. The alternate model demonstrates improved forecast accuracy, measured as reduced forecast error, when compared to the present model.

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I. INTRODUCTION

A. MOTIVATION

The 1989 Defense Management Review Decision, as well as the military drawdown associated with the end of the Cold War have resulted in considerable attention toward reducing the size of the Navy's infrastructure and improving management processes. As the infrastructure is reduced, so must the investment in spare parts to support the force structure.

In the decade of the 1980's, the value of the Department of Defense's inventory of secondary items - consumable and repairable spare and repair parts needed to support weapons systems and military personnel - increased from $43 billion to about $100 billion. According to one United States General Accounting Office (USGAO) Report, included in these inventories were excess supplies which totaled about $40 billion (USGAO, 1992). That same report stated "not only has DOD bought more than it needs, but it has failed to apply standards of economy or efficiency to the purchase, maintenance and distribution of its inventories" (USGAO, 1992). During the same period, Department of the Navy secondary item inventories increased from $10 billion to about $30 billion.

Prior to 1988, the Navy invested in three levels of inventory:

1. Consumer levels managed and stored aboard ships, at air bases and at industrial activities to support on site maintenance and consumption needs.

2. Intermediate levels managed and stored at Fleet and Industrial Supply Centers (FISCs) in CONUS and overseas and on board combat support ships to satisfy demand within geographic regions.

3. Wholesale inventories managed by Inventory Control Points (ICPs) and stored at Navy and Defense Logistics Agency supply depots to satisfy worldwide demand.

In 1989, the Navy began an inventory reduction effort, the Inventory Management Improvement Program (IMIP), which included over 300 separate initiatives to reduce Navy inventory investments. One of the most significant of these initiatives was to eliminate

CONUS intermediate level inventories. Intermediate level inventories were retained at overseas FISCs. IMIP also called for "better forecasting, levels setting, and related analytical models to more accurately establish requirements." (Mitchell, September/October 1990)

Defense Management Review Decision 901, "Reducing Supply System Costs" is also a major part of the Navy's inventory reduction plan. It is composed of a number of initiatives designed to improve Navy supply system operations, reduce inventory levels and introduce additional efficiencies in the management of spare parts. The current Navy DMRD 901 savings target is about $4 billion through fiscal year 1997, with a savings goal of $531 million in intermediate level inventories alone. (Chesley, July/August 1992)

In May 1990, the DOD Inventory Reduction Plan (IRP) was announced as a comprehensive initiative for improving underlying support systems in order to maintain current readiness levels with smaller inventories. Major points included in the IRP were:

1. Develop and implement mechanisms to respond quickly to changing requirements inherent in rapidly changing force structure and operating contingency scenarios.

2. Set quantitative, time phased goals to reduce material replenishment stockage objectives, i.e., safety levels, additive and non-demand based levels, procurement lead times, repair cycle requirements and order quantities to minimum essential requirements.

3. Review all categories of material retention stocks with particular attention to reducing economic, contingency and numeric retention categories. Establish objectives for timely disposal of non-essential or inactive material.

4. Review material stockage and retention levels at intermediate and consumer levels to ensure only essential levels are stocked. Reduce redundant stockage to minimum essential levels.

5. Institutionalize the above points by establishing a comprehensive program that will achieve long-term reduction of inventories while preserving military readiness. Implement personnel incentives to achieve minimum compliance with all aspects of the plan.

The focus during this period of inventory reduction must be to minimize impact on fleet readiness. Keller (May/June 1994) states that "as the Navy force structure continues to decline, our clear challenge is to continue to develop and execute low cost, innovative solutions to spares investments." In particular, the Navy's remaining intermediate level inventories will continue to be closely scrutinized for their performance in achieving the highest possible supply effectiveness while minimizing total inventory costs.

B. OBJECTIVES AND SCOPE

This study focuses on one Navy intermediate level allowance document and inventory, the Shorebased Consolidated Allowance List (SHORCAL) at the Fleet and Industrial Supply Center, Yokosuka, Japan. The SHORCAL inventory supports Navy and Marine Corps aircraft spare parts requirements in the Western Pacific region. A recent message from Rear Admiral Bondi, CINCPACFLT Fleet Supply Officer, to RADM Moore, Chief of the Navy Supply Corps (July 1994) expressed the importance of this inventory to WESTPAC aviation support:

> As I see FISC Yokosuka, it is and will continue to remain for the forseeable future critically important for: (a) support of deployed PACFLT/NAVCENT forces, (b) support of forward deployed ships homeported in Japan, (c) the major point of support in event of Korean contingency.
>
> In view (of the) above, (I) believe we need collectively to reexamine our stock positioning rationale and all policies which impact FISCs ability to fulfill her vital role in supporting PACFLT aviation requirements.

Seven selected Aviation Depot Level Repairable items (AVDLRs) from the SHORCAL are analyzed in this study. These items are used to evaluate the existing Yokosuka SHORCAL forecasting method and determine alternate forecasting methods.

C. ORGANIZATION OF THE THESIS

This thesis is organized into five chapters. The second chapter describes the Yokosuka SHORCAL. Supply performance measures applicable to the Yokosuka SHORCAL and the Yokosuka SHORCAL inventory model are explained. The data used in this study are presented. The third chapter discusses forecasting methods, including the existing Yokosuka SHORCAL AVDLR method and presents an alternate forecasting model for the Yokosuka SHORCAL. The fourth chapter presents the methodology and results of the study. The fifth chapter summarizes the results and conclusions of the study and provides recommendations for further research and consideration.

II. THE YOKOSUKA SHORCAL

A. THE SHORCAL CONCEPT

The SHORCAL is an authoritative document which lists repairable items and subassemblies required for aviation support. The document consists of lists of Aviation Depot Level Repairables (AVDLRs) and aviation consumables. The majority of AVDLRs are identified by the cognizance symbol 7R preceding the National Stock Number (NSN). Consumables are identified by the cognizance symbols 1RD or 1RM.

There are two types of SHORCALs: consumer level and intermediate level. Consumer level SHORCALs are tailored to specific allowances designed to support requirements specified in an approved maintenance plan and are tailored to a specific shorebased activity (i.e., Naval Air Station, Marine Air Group). Operating site maintenance, supply and flying hour data are used in the allowance determination. Periodic re-evaluation is conducted to reflect changes in the number and types of aircraft supported.

The Yokosuka SHORCAL is an intermediate level allowance document. Its inventory supports aviation ships assigned or deployed to the Western Pacific region and shore stations in the region. For aviation ships (CV, CVN, LHA, LPH), the Yokosuka SHORCAL inventory supplements on-board Aviation Consolidated Allowance List (AVCAL) inventories. The SHORCAL also supports Supplemental Aviation Spares Support (SASS) inventories. Formerly called "Pack-UP Kits," SASS inventories are made up of selected repairable items which support squadrons or parts of squadrons that have been detached from their parent activity to perform missions at other ashore or afloat locations. For example, a squadron's helicopter detachment assigned to a small combatant ship is supported by a SASS. The Yokosuka SHORCAL inventory also replenishes the consumer level SHORCAL inventories located at shore activities in the area.

The withdrawal of United States forces from the Philippines and the closure of the Subic Bay Naval Supply Depot in 1992 realigned supply functions in the western Pacific and Indian Ocean Theaters. FISC (then Naval Supply Depot) Yokosuka was selected to receive the majority of NSD Subic's SHORCAL material, totaling nearly 14,500 line items (Anderson, July/August 1992). Activities which had previously submitted requisitions to Subic as their point of entry were shifted to Yokosuka. Table 1 lists the operating areas of aviation and non-aviation ships having FISC Yokosuka as their requisition point of entry for aviation material.

SHIP TYPE	**OPERATING AREA**
AVIATION SHIPS (CV, CVN, LPH, LHA)	WESTPAC, including the Indian Ocean. Includes ships operating in MIDPAC 7 days or less en route to WESTPAC from CONUS and ships operating for more than 7 days north of the 30th parallel.
NON-AVIATION SHIPS	WESTPAC, including the Indian Ocean.

Table 1. Ship Operating Areas Having FISC Yokosuka As Requisition Point of Entry.

Table 2 lists Marine aviation units and ex-conus shore stations having FISC Yokosuka as their requisition point of entry (COMNAVAIRPAC, 1990).

USMC AVIATION UNITS	**EX-CONUS SHORE STATIONS**
Marine Air Group (MAG) 12/Marine Air Logistics Squadron (MALS) 12 MAG 36/MALS 36	NAF Atsugi, MCAS Iwakuni, MCAS Futenma, COMFLEACT Okinawa, NAF Misawa, NSF Diego Garcia

Table 2. USMC Aviation Units and Ex-Conus Shore Stations Having FISC Yokosuka as POE.

B. AVIATION REPAIRABLES MANAGEMENT

This section discusses the role of the Yokosuka SHORCAL in the management of WESTPAC AVDLRs.

Naval aviation maintenance is divided into three levels, organizational, intermediate and depot. When an installed aviation repairable item fails, it is removed from the aircraft by the organizational level (squadron) and turned into the supply department along with a requisition for a Ready For Issue (RFI) item. If the item is in stock, it is issued to the requesting squadron for reinstallation in the aircraft. The faulty, or non-RFI item is inducted for repair at the nearest Aviation Intermediate Maintenance Department (AIMD) or shipped to the depot level repair facility designated in the Master Repairable Items List (MRIL), depending on the maintenance code of the item. If the item is beyond the capability of intermediate level maintenance it is sent to the depot level for repair. If the item is repaired by the AIMD, the RFI item is placed back in supply department inventory, unless there is an outstanding demand waiting to be filled.

If the requested item is not in stock at the time it is requisitioned, and the ship or shore activity is within the FISC Yokosuka POE, a requsition is submitted to the Yokosuka SHORCAL to fill the requirement.

C. SUPPLY PERFORMANCE MEASURES

Each level of inventory is assigned supply performance measures in four areas: (1) response time goals, (2) point of entry availability goals, (3) net availability goals and (4) Average Customer Wait Time (ACWT) goals (NAVSUP, 1989, Enclosure (1)).

1. Response Time Goal

Response time begins when a requirement is placed and ends when the requested item is received at the designated delivery point (NAVSUP 1989, enclosure (1)). Uniform Material Movement and Issue Priority System (UMMIPS) time standards are in effect for the Yokosuka SHORCAL intermediate level of inventory. The response time is set no longer than 11 days for issue priority groups I and II (assignments of mission essentiality) (OPNAV, 1992, Enclosure (5)).

2. Point of Entry Availability Goal

Point of Entry (POE) availability is expressed as a percent of total demand, for standard stocked and non-stocked items, received and filled from on-hand inventory (NAVSUP 1989, Enclosure (1)). POE Availability for the Yokosuka SHORCAL is 70 percent. The formula for computing POE Availability is represented as:

$$POE\ AVAILABILITY\% = \frac{DEMAND\ \ FILLED\ FROM\ \ STOCKED\ ITEMS}{DEMAND\ \ FOR\ STOCKED\ AND\ \ NON\ STOCKED\ \ ITEMS} \times 100 \quad (2.1)$$

3. Net Availability Goal

Net availability is expressed as a percent of total demand, for standard stocked items, received and filled from on-hand inventory. The net availability goal for the Yokosuka SHORCAL is 85 percent. The formula for computing net availability is represented as:

$$NET\ AVAILABILITY\% = \frac{DEMAND\ \ FILLED\ FROM\ \ STOCKED\ ITEMS}{TOTAL\ DEMAND\ \ FOR\ STOCKED\ ITEMS} \times 100 \quad (2.2)$$

4. Average Customer Wait Time (ACWT) Goal

The Average Customer Wait Time Goal for Yokosuka is established by Naval Supply Systems Command at 135 hours from the time a requirement is placed until the time material is received (NAVSUP, 1989, Enclosure (1)).

D. SHORCAL INVENTORY MODEL

The Yokosuka SHORCAL inventory allowances are established using different models based on the type of material. There are two types of material in the SHORCAL inventory: (1) aviation consumables, designated by cognizance symbols 1RM and 1RD and (2) aviation depot level repairables, designated by cognizance symbol 7R. Depot level repairables differ from consumables in their method of maintenance and recoverability or condemnation upon removal of the item from the system at the time of item failure. All stock numbered items are assigned a five digit code called a source, maintenance and recoverability/condemnation code. Depot level repairables are assigned particular maintenance and recoverability/condemnation codes which specify turn-in of the faulty item to an aviation intermediate level maintenance facility or a depot level overhaul point for repair and reuse. There are approximately 5,000 1R cog and 7,000 7R cog line items of inventory in the SHORCAL.

1. 1RM Consumables

For aviation consumables designated by cognizance symbol 1RM, the Variable Operating and Safety Level (VOSL) Function is used. VOSL uses the Economic Range Model (ERM) to determine if an item is a candidate for stockage (range determination). The ERM computes the advantages and disadvantages of stocking an item. The advantage is determined by the number of requisitions an item would satisfy based on forecasted demand. The disadvantage is the cost of average on hand inventory. The objective of the ERM is to maximize the number of requisitions satisfied in a quarter subject to constraints on range, workload, investment and turbulence (additions and deletions from inventory).

To determine the quantity of each item to be carried (depth determination) VOSL's objective is to obtain maximum requisition effectiveness for carried items within funding constraints. It does this by classifying inventory into categories of Value Added Demand (VADCATS). For each VADCAT, there is a corresponding operating level factor expressed in terms of months of supply. FISC Yokosuka runs program D-UB39 quarterly using the Uniform Automated Data Processing System - Stock Point (UADPS-SP) to update demand-based requirement levels (NAVSUP, 1989, Enclosure (6)). The overall goal of VOSL is to achieve net effectiveness goals (ASO, September 1993, p. 2).

2. 1RD Aviation Consumables and 7R Aviation Depot Level Repairables

a. Determination of Range and Allowance Quantities

Allowances for 1RD and 7R cog items are established on a demand basis. Initial stockage criteria is based on a specified number of demands received in a specified period of time and the unit price of the item. For 1RD consumables, an item must have two demands in a 12 month period to qualify for stockage. For 7R cog repairables, items with a unit price of $5,000 or more are stocked if the actual demand is equal to or greater than one in a six month period. Items with a unit cost of less than $5,000 become candidates to be stocked if the actual demand is greater than one in a nine month period. (NAVSUP, 1989)

Once selected as an inventory item, the quantity (inventory depth) must be determined. When a new system is fielded, spares requirements are determined from initial failure rates calculated during system development. Using these failure rates, the stockage quantity is set at the number of failures that would be incurred in total wartime flying hours over a 60 day period. If, after 18 months there is no further demand for the item, it is dropped from the inventory. (Marcinkus, October/November 1994)

After sufficient demand history has been collected, quantities are established based on actual demand over time. The allowance for an item, known as the Requisitioning Objective (RO), is the sum of three levels - an Operating Level (OL), an Order and Ship Time Level (OSTL) and a Safety Level (SL), all measured in terms of days of demand. The operating level is the amount of material required to meet mean demand during a certain number of days. The order and ship time level is mean lead time demand, beginning when the order is placed and ending when the order arrives. The safety level is safety or buffer stock, also expressed in days of demand, which allows for variability in demand and lead time.

Demand history is used in determination of allowance quantities for SHORCAL AVDLRs. Twelve months of historical demand data is used to determine the total number of demands per item. The allowance quantity is then computed as 124 days of historical demand, consisting of 60 days Operating Level (OL), 34 days Order and Ship Time Level (OSTL), and 30 days Safety Level (SL). This re-evaluation process is conducted annually by the Aviation Supply Office (ASO). Representatives of FISC Yokosuka and ASO also negotiate allowance levels based on changes in demand, changes in aircraft deckload of supported retail sites and changes in the repair cycle pipeline (Marcinkus, October/November 1994). The formula used in the computation is as follows:

$$ALLOWANCE\ QUANTITY = \frac{TOTAL\ ANNUAL\ DEMAND\ PER\ ITEM}{4} \times \frac{124}{90} \quad (2.3)$$

b. Reorder Points

The reorder point is based on whether the inventory system is a fixed order size system (Q-system) or a fixed order interval system (P-system). With a fixed order size system, the inventory position (defined as on-hand plus on-order minus backorders) is reviewed on a continuous basis. When the inventory position falls to the predetermined reorder point, an order is placed to bring the inventory position back up to allowance. With a fixed order interval system, the inventory position is reviewed on a periodic basis. At the time of review, if the inventory position is above the reorder point, nothing is done. If, however, the inventory position is at or below the predetermined reorder point, an order is placed to bring the inventory position back up to allowance. (Tersine, 1994)

For 1RD and 7R cog items in the Yokosuka SHORCAL, a fixed order interval system is used. All line items are reviewed once per week. If an item's inventory position is found to be at or below the reorder point, an order is placed to bring it up to allowance. For repairables, the reorder point is always the point at which the inventory position is one unit below the allowance quantity.

3. Changing Allowance Levels

Between SHORCAL reviews, the process still accommodates changes in the range and depth of AVDLR items. The FISC reviews allowances monthly and submits Allowance Change Requests to ASO based on predicted increases or decreases in demand. ASO reviews the ACRs and approves or disapproves the requested allowance. If an allowance increase is approved, FISC submits a requisition for the amount of the increase. If an allowance decrease is approved, FISC turns the ready-for-issue material into the supply system for use by another activity.

E. THE DATA

This section discusses the historical demand data used in this study and overall SHORCAL performance measures during the period examined.

1. Historical Demand Data

Historical demand data were provided to the author in the form of UADPS-SP computer print outs by FISC Yokosuka. These data covered approximately twelve months from July 1993 through June 1994. Seven different AVDLR items were selected by FISC Yokosuka for the study. Table 3 lists the items, along with a brief description of each and a listing of the aircraft types in which they are installed. Standard price refers to the price listed in the Management List - Navy (ML-N) if an AVDLR carcass is not available for turn-in to the designated repair activity listed in the Master Repairable Items List (MRIL). Net price is the price charged if a carcass is available and turned in.

2. Data Tabulation

The historical demand data for the AVDLRs was tabulated using LOTUS 1-2-3 spreadsheet for purposes of further analysis. Appendix A lists the tabulated data for each item along with a description of the data columns. Appendix B lists Unit Identification Codes along with the associated activity names.

3. Aggregate Demand - July 1993 through June 1994

The seven items examined in this study were chosen by FISC Yokosuka due to their high variability in demand. There were a total of 479 demands for all items during the period. Figure 1 graphs aggregate demand for all seven items and illustrates this "lumpy" demand pattern. Appendix C provides individual graphs of demand for each item over time.

F. SHORCAL HISTORY - JULY 1993 THROUGH JUNE 1994

The Yokosuka SHORCAL consists of approximately 12,000 line items. Of these, approximately 7,000 are AVDLR (7R cog) items and the rest are 1R cog items. Table 4 provides the top customers of the SHORCAL for the period July 1993 through June 1994 along with the total number of demands for each.

1. Performance History

During the period July 1993 through June 1994, the SHORCAL had a Point of Entry Availability of 62.8 percent for 1R cog items and 54.8 percent for 7R cog items (goal - 70 percent). During the same period, the net availability was 80.5 percent for 1R cog items and 69.2 percent for 7R cog items (goal - 85 percent).

NATIONAL STOCK NUMBER	NOMENCLATURE	UNIT PRICE STANDARD/NET	INSTALLED AIRCRAFT TYPES
5826-00-117-4629	BEARING INDICATOR	13800 / 2050	P3
6610-00-133-7868	COUNTING INDICATOR	1900 / 843	EA3, EA6, A6, C130, F14, F4, S3, T34, OV8
6615-00-182-7733	DISPLACEMENT GYROSCOPE	32390 / 4240	EA3, EA6, ERA3, E2, P3, CH46, RH53, UH2, SH2, SH3
5895-01-040-1531	ELECTRONIC COMMUNICATION CASE	5680 / 1040	A4, A6, C2, EA3, E2, F14, F5, S3, P3, CH46, RH53, UH2, SH2, SH3
6610-01-088-2352	ATTITUDE INDICATOR	6550 / 4070	A6, EA6, S3
5841-01-120-4885	HEIGHT INDICATOR	5990 / 2290	F18
5895-01-162-9449	RADIO RECEIVER	3720 / 1180	F18, EA6, SH3, F14, AH1, SH53, P3, AV8, A6, SH60, HH60

Table 3. Descriptions of National Stock Numbers.

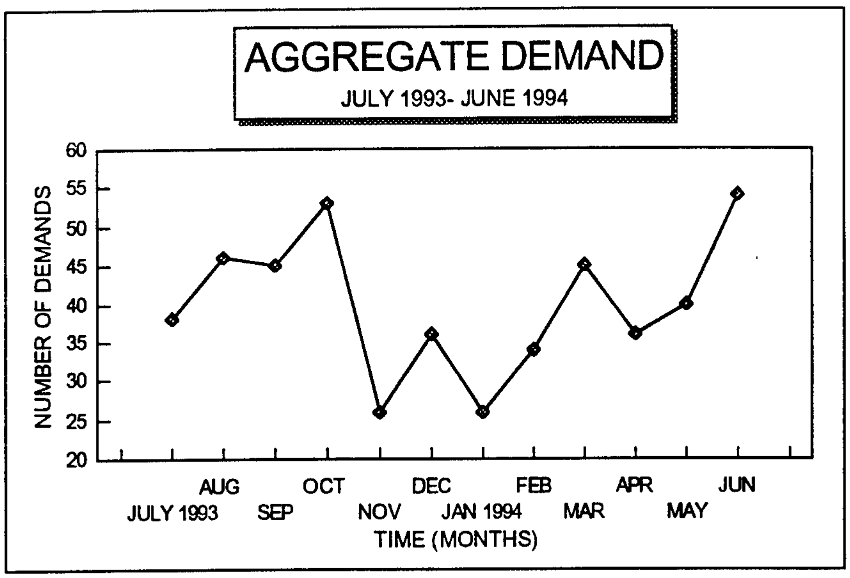


Figure 1. Aggregate Demand Over Time.

CUSTOMER	DEMANDS
1. USS INDIANAPOLIS (CV-62)	17,026
2. MARINE AIR LOGISTICS SQUADRON 12	12,969
3. MARINE AIR LOGISTICS SQUADRON 36	10,828
4. USS ABRAHAM LINCOLN (CVN-72)	6,618
5. USS CARL VINSON (CVN-70)	4,564
6. NAF ATSUGI	3,439
7. MAF MISAWA	1,988
8. USS KITTY HAWK (CV-63)	3,380
9. USS NEW ORLEANS (LPH-11)	1,280
10. USS PELELIU (LHA-5)	1,089
11. USS BELLEAU WOOD (LHA-3)	1,047
12. MCAS IWAKUNI	372
13. USS TRIPOLI (LPH-10)	250
14. USS CURTS (FFG-38)	53
15. USS MCCLUSKY (FFG-41)	50
16. USS OBRIEN (DD-975)	48
17. USS BLUE RIDGE (LCC-19)	35
18. USS HEWITT (DD-966	26
19. USS THATCH (FFG-43)	26

Table 4. Top Customers of FISC Yokosuka SHORCAL, July 1993-June 1994.

III. FORECASTING DEMAND FOR THE YOKOSUKA SHORCAL

This chapter discusses the current Yokosuka SHORCAL forecasting model and an alternate forecasting model for the SHORCAL.

A. THE YOKOSUKA SHORCAL FORECASTING MODEL

The current Yokosuka SHORCAL forecasting model uses a time series method. The demand forecast is obtained by extrapolating past data into the future. Two factors are used in time-series models: the data series to be forecast and time. There is an underlying assumption in a time-series forecast that some pattern or combination of patterns is recurring over time. Time-series forecasting assumes that the pattern can be derived solely on the basis of historical data from the series. There is no attempt to discover the factors influencing the behavior of the system. There are three reasons for this. First, the system may not be understood or it may be too difficult to interpret the reasons for its behavior. Second, there may be no interest in understanding the "why", only the "what". Third, the cost of understanding the "why" may be extremely high, while the cost of the "what" - the time-series method - may be relatively low. (Wheelwright and Makridakis, 1985)

1. The Current Yokosuka Time Series Model

The current Yokosuka model uses a moving average smoothing method. Smoothing models attempt to distinguish between random components and the basic underlying patterns through a process that eliminates the extreme values and bases a forecast on intermediate values. Moving averages simply take a portion of a data series and average it, then use this average as the forecast for the next period. Moving average forecast models can generally be represented by the following formula:

$$\hat{Y}_t = \frac{Y_{t-1}+Y_{t-2}+Y_{t-3} \cdots +Y_{t-n}}{n} = \frac{\sum_{i=1}^{n} Y_{t-i}}{n} \tag{3.1}$$

where Y is the actual demand and n is the number of periods in the forecast interval. The interval for averaging in the current Yokosuka model is one year, corresponding to the time between SHORCAL reevaluation. This model averages the total demand for an item over a year and uses that value as the forecast for each month of the following year. The formula for computation of the forecast is as follows:

$$\hat{Y}_t = \frac{(Y_1 + Y_2 + Y_3 \dots + Y_{12})}{12} = \frac{(\sum_{t=1}^{12} Y_t)}{12} \tag{3.2}$$

This model requires a year of historical demand to compute the forecast. Represented graphically, it smoothes the forecast to a horizontal line. Figure 2 illustrates this by comparing the actual demand, three month moving average, six month moving average and the Yokosuka forecasting models, using aggregate demand for all seven items. This comparison shows that as more observations are included in the moving average, the range of the forecast decreases. Thus, changing the number of periods has an effect on the amount of smoothing. If a smoother value is desired, either because it is believed the historical data contain considerable randomness or because it is believed there will be little change in the underlying pattern, a large number of observations should be used to compute the forecast. If, however, it is believed that the underlying data pattern is changing in a time-series and there is minimal randomness inherent in the observed values, a smaller number of observations should be used to compute the forecast. (Tersine, 1994)

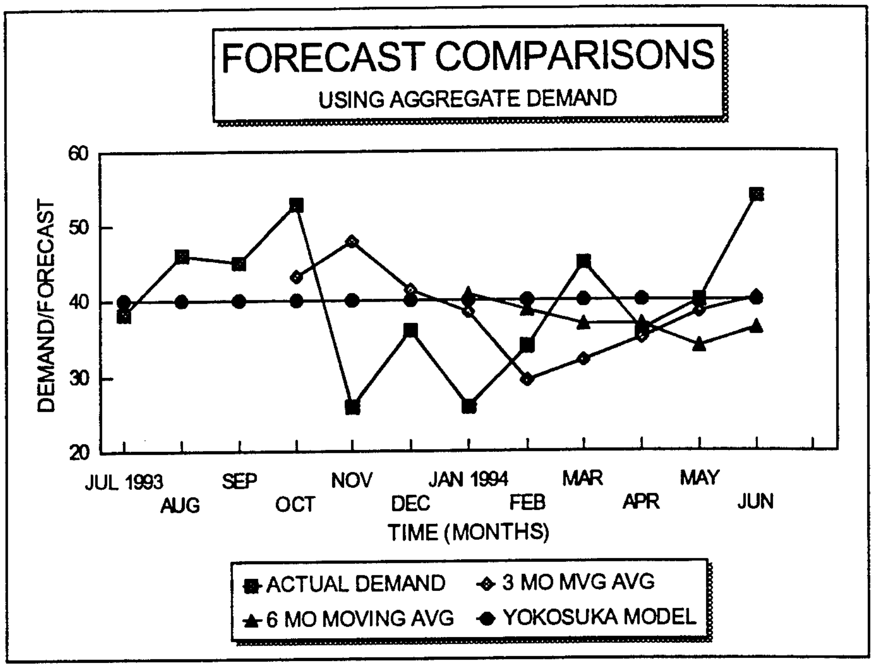


Figure 2. A Comparison of Forecasting Models With the Yokosuka Model.

B. SELECTION OF AN ALTERNATE FORECASTING MODEL

Abraham and Ledolter (1983) identify the following five criteria for selection of the appropriate forecasting model: (1) the degree of accuracy required, (2) the length of the forecast horizon, (3) how high a cost for forecast production can be tolerated, (4) the degree of complexity required and (5) data availability.

Forecast accuracy is the most important criterion for choosing a forecasting method. The degree of accuracy required depends in large part on the cost of inaccuracy. A poor forecast of demand generally results in higher stockout costs. However, increasing forecast accuracy usually raises the costs of data acquisition, computer time and personnel. Data costs and computer acquisition costs are increasingly becoming an insignificant part of technique selection. This study identifies the most accurate forecast for the Yokosuka SHORCAL (by minimizing forecast error) based on the forecast's expected value, conditional on the historical value up to and including the last period of available demand history.

The forecasting model which is the most complex is not necessarily the most desirable. Often the simplest model which is easiest to use, understand and explain is preferable. This is stated in the Principle of Parsimony, "...in a choice among competing hypotheses, other things being equal, the simplest is preferable" (Box and Jenkins, 1976). The reason for this is that unnecessary parameters increase the variance of the prediction error.

The choice of the appropriate forecasting model(s) for the Yokosuka SHORCAL is based on separating demand history into two categories: (1) aircraft carrier demand, defined as demand originating from carriers having Yokosuka as their point of entry for off-ship requisitions and (2) non-aircraft carrier demand, defined as demand originating from all other customers. Separating demand in this manner yields 255 total carrier demands for the seven items over the 12 month period July 1993 through June 1994. Figure 3 illustrates the aggregate carrier demand pattern over time:

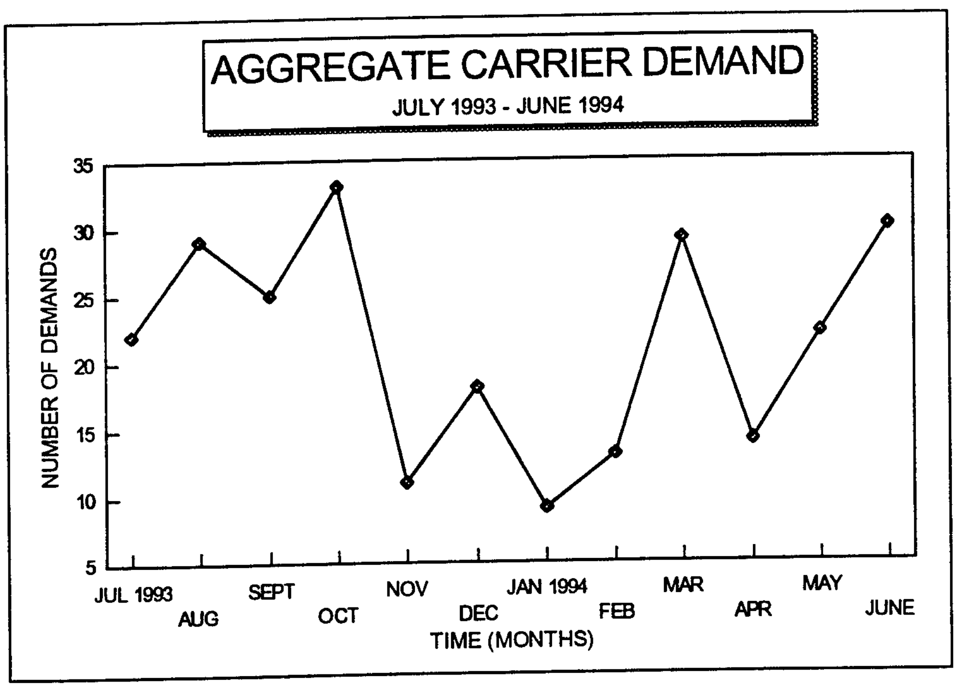


Figure 3. Carrier Demand Over Time.

There are 224 aggregate non-carrier demands for the seven items over the same time period. Figure 4 shows the demand pattern over time:

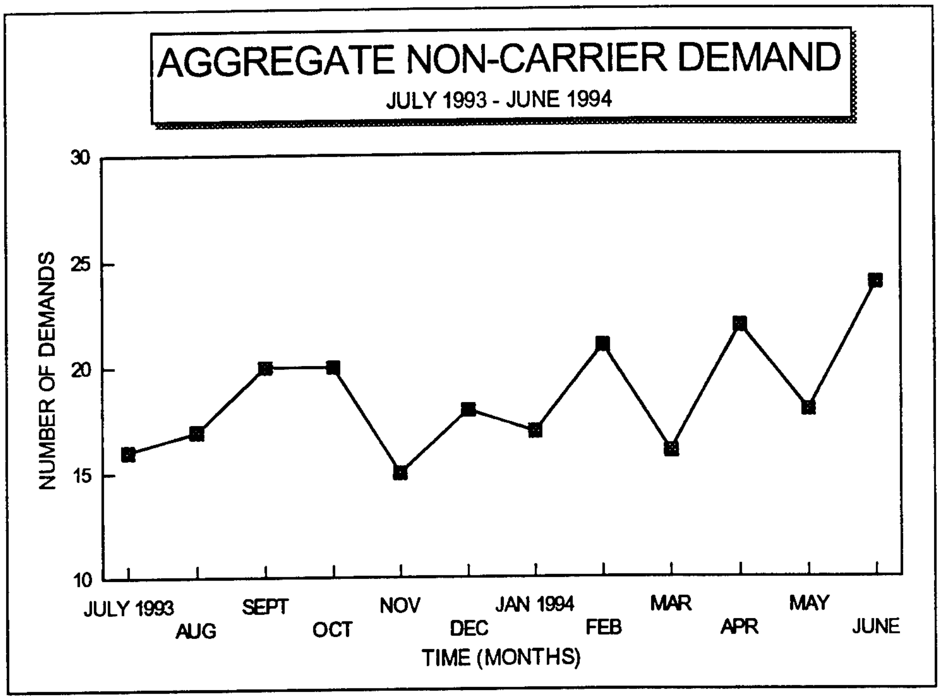


Figure 4. Non-Carrier Demand Over Time.

Demand is segregated for the following reasons:

1. There is a cause and effect relationship between aircraft carrier presence and operating tempo with demand.

2. There are a small number of potential carrier customers (five) generating approximately 50 percent of total demand on the SHORCAL.

3. Non-carrier demand involves a large number of customer activities having widely varying requirements in terms of the range and quantity of material demanded.

4. The aircraft carriers have similar missions, and, with minor differences, support similar types and quantities of aircraft. There are a relatively small number of independent variables which affect demand for spares.

5. Non-carrier customers have dissimilar missions and carry multiple aircraft types and quantities. There are a large number of variables affecting demand for spares and if there is interdependency between them, it difficult to measure.

C. THE ALTERNATE YOKOSUKA SHORCAL FORECASTING MODEL

The alternate Yokosuka forecasting model consists of two sections: (1) causal forecasting of carrier demand and (2) separate forecasts of non-carrier demand and residuals from the causal carrier forecast. Forecasts computed in the two sections are then added together to obtain the total forecast for the item. Two different methods of forecasting non-carrier demand and carrier residuals are presented. The first method uses time series analyses and the second uses a marginal value approach. Subsequent sections explain the model. Figure 5 illustrates the basic model:

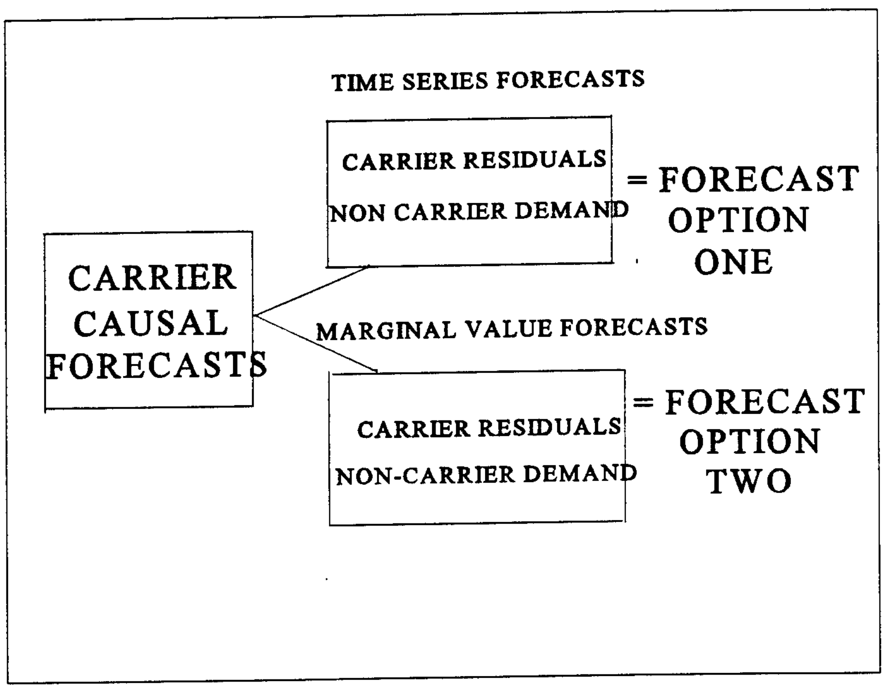


Figure 5. The Alternate Forecasting Model.

1. Causal Forecasting of Carrier Demand

a. Causal Forecasting Overview

With causal forecasting models, there is a cause and effect relationship between inputs and output such that a change in inputs affects the output in a predictable way. Inputs are known as the independent variable and output is the dependent variable. The process of building a causal forecasting model involves determining cause and effect relationships in order to predict the future states of a system, provided the inputs for those future states can be estimated. In general, independent variables other than time are used in causal models.

The advantage of causal models is that a range of forecasts can be developed corresponding to a range of variables. The disadvantage is that the data requirements are generally much larger than time series models, since information is required on the input variables as well as the variable being forecasted. In addition, these models take longer to develop and are much more sensitive to changes in the underlying relationships than a time series model.

b. Regression Models

Simple regression deals with a relationship between one independent variable and one dependent variable. If the independent variable is time, it is called time-series regression. If time is not the independent variable, it is called cross-sectional regression. In simple regression, the assumption is that the functional relationship between two variables can be represented as a straight line:

$$\hat{Y} = \alpha + \beta X + \varepsilon \qquad (3.3)$$

where α is the point at which the straight line intersects the Y axis, β is the regression coefficient, indicating how much the forecast changes when the independent variable, X, changes by one unit and ε is the random, or residual error. Non-linear relationships can be made linear through the use of logarithmic, polynomial or other transformations. Simple regression uses the method of least squares to find the "best fit" of a straight line to historical observations. This method minimizes the distance between the actual observations and the points on the regression line. A weakness of time series regression is that it gives equal weight to each observation and does not give more weight to recent observations.

Multiple regression is used in instances where one independent variable is inadequate to forecast a certain independent variable. This approach also uses the method of least squares, however it is more complex because since multiple independent variables are considered, a "best fit" between observations on more than two axes must be found. This is the method used in this study to forecast carrier demand.

c. *Basic Steps in Causal Forecasting*

In causal forecasting, it is necessary to first hypothesize certain relationships between variables and then determine which is most appropriate. Wheelwright and Makridakis (1985) outline the following basic steps in formulating causal models:

1. Formulate the Problem. The problem to be solved must be stated. In this phase the dependent variable is defined and the candidate independent variables are identified.

2. Test Plausible Regression Equations. This initial run includes the data on all independent variables.

3. Decide Among Individual Regressions. In this step, a computer program is used to determine the coefficients of the regression equations based on the data.

4. Check the Validity of Regression Assumptions. In this step the validity of the regression is determined using the t-test, F-test and Durbin-Watson (D-W) statistic, which will be discussed further in a subsequent section.

5. Prepare a Forecast. Once the validity of the regression has been determined, the equation can be used to prepare a forecast. This is done using estimated values of the independent variables rather than actual values. In so doing, the confidence interval for the forecast and the accuracy of the values of the independent variable must be determined. This is because the accuracy of the forecast is only as good as the accuracy of the independent variables used in forecast determination.

d. *Types of Variables in the Causal Forecasting Model*

The purpose of the independent variables is to "explain" the variation in the dependent variable (Levenbach and Cleary, 1984). There are two categories of these explanatory variables which can be used: endogenous and exogenous.

Endogenous variables are those which are determined within the system. In other words, the decision maker has control over them. Because of this control, their future values can be estimated. The degree of control dictates the confidence of the predictions. The following examples of these variables affect demand on the Yokosuka SHORCAL:

1. The number of flight hours per aircraft type, model and series in a given time period;
2. The frequency and length of carrier deployments;
3. The number of sorties per day by aircraft type, model and series;
4. The carrier deckload i.e., the configuration of aircraft by type, model and series, which varies from carrier to carrier and from deployment to deployment;
5. The planned operational scenario for the carrier's deployment;
6. The provisioning of the carrier's AVCAL, the onboard aviation allowance list;
7. The logistics environment in which the carrier will operate;
8. The carrier's operating budget;
9. Inherent aircraft reliability and maintainability factors; and
10. Maintenance capability.

Exogenous variables are determined outside the system. They are controlled by factors outside the decision maker's control. Since these variables are difficult to predict and anticipate, they affect the randomness of the model output. Examples of these are:

1. The military environment and the domestic and worldwide political climate which dictate the carrier's operating tempo and actual operating scenario;

2. External threats to the carrier's logistics pipeline;

3. Changes in the budget due to political action; and

4. Design flaws and configuration changes in supported systems which affect support requirements.

For purposes of this study, two endogenous decision variables are used, aircraft flying hours per month by type, model, and series, and the frequency and length of carrier deployments. These decision variables are used due to their high degree of correlation to demand, the ready availability of historical data to estimate model parameters, and the availability of future estimates of the variables for forecasting.

e. *The Basic Causal Forecasting Model*

The relationship between the independent variables and the dependent variable is expressed as follows:

$$D = f\{F, C\} \tag{3.4}$$

where D is the monthly demand for each item, F is flying hours by aircraft type, model and series and C is a quantitative measure indicating whether or not a carrier is deployed.

f. *Causal Forecast Error*

Statistical analysis of the significance and precision of regressions is used to make statements about the likelihood that forecasted values will vary from actual future values by certain amounts, the confidence in having determined the accuracy of a straight line and the accuracy of the coefficients α and β. The following tests are used in determining the statistical significance of regressions:

(1) The t-Statistic. The t-Statistic measures the statistical significance of the regression coefficient for an independent variable. The t-distribution is used when the sample size, n, is small. The t-distribution is shorter and more spread out than the standard normal distribution. As n increases, the spread of the t-curve decreases. As n approaches infinity, the t-curve approaches the standard normal curve (Devore, 1991). When $n < 30$,

the observed t-value should be greater than approximately 2.0 in absolute value for significance at the 95 percent level. If this occurs, a statistically significant value not equal to zero exists for the coefficient. If the observed t-value is not significantly different from zero, the regression can be recomputed using additional data or the variable deleted from the model.

(2) R-Squared. Also called the correlation coefficient, R-squared is the explained variation from the mean value, divided by the total variation from the actual value. This is expressed as:

$$r^2 = \frac{explained\ \ variation}{total\ \ variation} \tag{3.5}$$

where r^2 is a value from zero to one. An R-squared value close to one does not necessarily mean that the model is "good". It is a measurement of the variation in the data explained by the model.

(3) The F-Statistic. The F-statistic provides an overall test of significance of the entire model. It does this by comparing the explained variance to the unexplained variance, expressed as:

$$F = \frac{explained\ \ variance}{unexplained\ \ variance} \tag{3.6}$$

The value of F must be compared to an entry in a table of values to determine significance. (Wheelright and Makridakis,1985)

(4) The Durbin-Watson Statistic. In regression, it is important to check for autocorrelated errors. An underlying assumption in regression is that residual values (the difference between the forecast value and the actual value) are independent of those coming before or after. When this assumption is not met, autocorrelation exists among

residuals. A value of the D-W statistic of about 1.5 to 2.5 implies an absence of autocorrelation. (Wheelwright and Makridakis, 1985)

2. Forecasting Carrier Residuals and Non-Carrier Demand

Section two of the model involves forecasting two types of data, residual values from the carrier causal model and non-carrier demand. Two methods are used to forecast these data: (1) time series forecasting and (2) the marginal value approach.

a. *Time Series Models*

The forecasts for carrier residuals and non-carrier demand are determined by comparing four different time series forecasting methods for each item: (1) the naive model, (2) the three month moving average model, (3) the Exponentially Weighted Moving Average model (EWMA) and (4) the EMWA model adjusted for trend. In all models (except the three month moving average model) the initial forecast value used for the first period is the actual demand for the first period.

The naive model uses as a forecast the most recent actual value as the forecast for the next period. The naive model is also referred to as the "random walk". It is often used as a benchmark against which other time-series models are judged. The naive model uses demand from the last period as the forecast for the current period. This is expressed as:

$$\hat{Y}_t = Y_{t-1} \tag{3.7}$$

The moving average model is discussed in a previous section. A three month moving average period is selected because it is long enough to cancel out random fluctuations in demand and short enough to discard irrelevant information from the past. Mathematically, the three month model is:

$$\hat{Y}_3 = \sum_{i=1}^{3} \frac{Y_i}{3} \tag{3.8}$$

Exponential smoothing is a moving average method that assigns weight to the observed data so that decreasing weights are given to older observed values. The exponentially weighted moving average model is similar to the basic moving average model except that it places more weight on the more recent observations. This model uses a smoothing constant, α, as a weighting factor. The formula for the EWMA forecast is:

$$\hat{Y}_t = \alpha (Y_{t-1}) + (1 - \alpha) \hat{Y}_{t-1} \tag{3.9}$$

where $0 < \alpha < 1$. As the value of the smoothing constant approaches one, the forecast value approaches that of the naive model. Various combinations of the smoothing constant are tried until the forecast with the lowest Mean Absolute Deviation (MAD) is found. The MAD is the average absolute error and is computed as follows:

$$MAD = \frac{\sum_{i=1}^{n} |Y_i - \hat{Y}_i|}{n} \tag{3.10}$$

The trend adjusted EWMA model uses two smoothing constants, α and β. The constant β is used to smooth any upward or downward trend that may exist in the data. First, the forecast level is computed using the previous trend:

$$\hat{X}_t = \alpha (Y_{t-1}) + (1 - \alpha)(\hat{Y}_{t-1} + T_{t-1}) \tag{3.11}$$

This forecast level is used to update the trend, where the apparent trend for each period is the difference between forecast levels. By smoothing the difference with the previous trend by using the smoothing constant for trend, β, the trend for each period is adjusted as follows:

$$T_t = \beta(\hat{X}_t - \hat{X}_{t-1}) + (1 - \beta)T_{t-1} \tag{3.12}$$

where $0 < \beta < 1$. Various combinations of the smoothing constants are tried until the constants are found which result in the lowest MAD. The forecast for time period t is then determined as:

$$\hat{Y}_t = \hat{X}_t + T_t \tag{3.13}$$

Finally, the forecast for n time periods beyond t is estimated as:

$$\hat{Y}_{t+n} = \hat{X}_t + (n + 1)T_t \tag{3.14}$$

b. The Marginal Value Method

This method uses the probability distibution of demand and the principles of decision making under risk to arrive at the best forecast.

The first step in this approach is to determine the discrete frequency distribution of carrier residuals and non-carrier demand for each item. This can be easily determined from the data. After that, the ordering cost must be determined. Ordering cost includes such elements as the stock point's receipt and stowage costs and the salaries of personnel involved in inventory control and contracting. The next step is to determine the cost of not having the item, which is the per unit stockout cost.

Stockout cost for the military is defined as the cost of lost readiness. When a spare part for an aircraft is not available upon item failure, a stockout cost is incurred which is equal to the degradation in readiness. If the stockout results in the grounding of the aircraft, the stockout cost is equal to the total grounding cost during the out of service period. If the stockout results in partial mission degradation, the stockout cost is measured by how much the item's mission criticality applies to the total grounding cost.

The next step is to find the optimum stockout probability. This is the point at which the cost is minimized with respect to the forecasted demand. The components of cost are ordering cost, purchase cost and stockout cost. This is written in equation form as:

$$EC = C + PQ + A\int_{Q}^{\infty} (M-Q)\, f(M)dM \tag{3.15}$$

where EC is the expected cost, C is the ordering cost, P is the item's unit price, A is the stockout cost per unit, M is the demand in units and Q is the forecasted demand (order quantity). To find the minimum expected cost the derivative with respect to Q must be calculated and set equal to zero. This results in:

$$\frac{\partial EC}{\partial Q} = P - A\int_{Q}^{\infty} f(M)dM = 0 \tag{3.16}$$

where:

$$\int_{Q}^{\infty} f(M)dM \tag{3.17}$$

is the stockout probability, i.e., the probability that demand is greater than the quantity ordered, or $p(M>Q)$. Solving for $p(M>Q)$:

$$p(M>Q) = \frac{P}{A} \tag{3.18}$$

The optimum quantity, Q*, occurs where *P/A* intersects the complementary cumulative distribution function for demand. This is shown graphically in Figure 6 as:

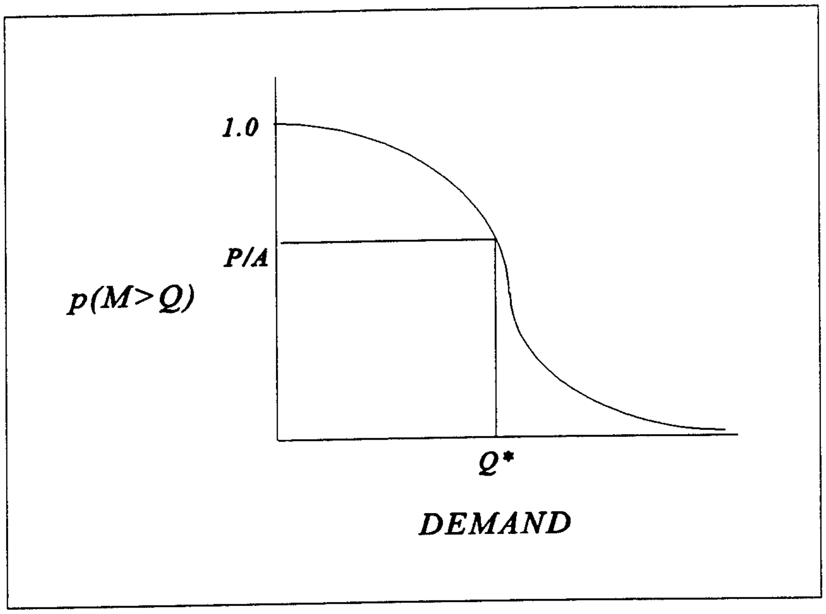


Figure 6. The Optimum Order Quantity.

When working with a discrete demand distribution, as in the case of this model, the optimum value of forecasted demand is not desired, since we are working with integers. Therefore we are looking for the best integer value as opposed to the optimal value. To find this value, the optimal stockout probability is first calculated as before. This probability will lie between two values which correspond to the probability that actual demand will exceed the forecasted demand. This probability is written as:

$$1 - \sum_{M=0}^{Q} P(M) \tag{3.19}$$

The largest forecasted discrete demand quantity that satisfies the smaller of the two values should be chosen as the best forecast.

IV. METHODOLOGY AND RESULTS

This chapter describes the methodology of the model and uses it to obtain forecasts for the seven NSNs. These forecasts are then compared to those obtained using the current model.

A. MODEL STRUCTURE

Historical demand data for each item is first separated into two categories: demand originating from carriers and demand originating from non-carrier customers. It is possible that an item may have only carrier demand, only non-carrier demand, or both carrier and non-carrier demand. This depends on the type(s) of aircraft in which an item is installed. If an item has both carrier and non-carrier demand, the forecast for demand is expressed as:

$$\hat{Y}_t = (C_t + TS_R) + TS_N \tag{4.1}$$

or:

$$\hat{Y}_t = (C_t + MV_R) + MV_N \tag{4.2}$$

where C_t is the causal forecast of carrier demand, TS_R is the time-series forecast of carrier demand residuals, TS_N is the time-series forecast of non-carrier demand, MV_R is the marginal value forecast of carrier demand residuals and MV_N is the marginal value forecast of non-carrier demand. A carrier demand residual, which is the difference between the actual carrier demand for a given item during a certain month t and the causal forecast of the item for that month, can be written as:

$$RESIDUAL = \varepsilon = Y_t - \hat{Y}_t \tag{4.3}$$

The residual value can be either positive or negative, depending on whether the actual demand was larger or smaller than the forecast. If the item has only carrier demand, the forecast for non-carrier demand is zero and the model is rewritten as:

$$\hat{Y}_t = (C_t + TS_R) \tag{4.4}$$

or:

$$\hat{Y}_t = (C_t + MV_R) \tag{4.5}$$

If the item has only non-carrier demand, the forecast for carrier demand is zero. The model then becomes:

$$\hat{Y}_t = TS_N \tag{4.6}$$

or:

$$\hat{Y}_t = MV_N \tag{4.7}$$

B. CAUSAL FORECASTING METHODOLOGY

1. Model Variables

a. *Explanatory Variable*

Flying hours are used as the explanatory variable in the model for carrier demand. This is because as flying hours per aircraft change over time, individual component failure on the aircraft will increase or decrease, thus affecting demand for spare parts. With flying hours as an explanatory variable, the equation for the causal forecast during month *t* is:

$$C_t = \alpha + \beta \ (\mathit{Flying\ Hours})_t \tag{4.8}$$

The forecast value must be non-negative, since negative demand for spare parts has no physical meaning. The β coefficients should be positive because flying an aircraft should result in more demand for spare parts, not less demand.

Aircraft flying hours for three carriers by aircraft type were obtained from the Customer Operations Division of the Naval Aviation Supply Office. Flying hours for these carriers by aircraft type were then added together to get total flying hours per aircraft type. Table 5 lists these flying hours by aircraft type.

MONTH	A-6E	EA-6B	E-2C	S-3B	F-14	F/A-18	SH-3H	SH-60F	HH-60H
JUL 93	361	150	0	464	405	405	137	49	0
AUG	1096	413	369	512	2049	703	159	363	172
SEP	1105	525	542	658	2588	753	354	422	187
OCT	1121	368	427	703	1931	625	222	414	294
NOV	347	118	156	212	821	0	0	241	88
DEC 94	539	200	256	285	519	895	415	0	0
JAN	606	244	275	323	551	1002	521	0	0
FEB	387	208	254	314	741	425	444	57	15
MAR	609	165	283	368	891	917	199	208	79
APR	839	318	393	447	1338	1725	252	327	122
MAY	891	386	505	503	1290	1792	289	408	130
JUN	921	308	494	672	1333	1482	368	307	84

Table 5. Monthly Flying Hours By Aircraft Type.

Since a NSN can be used on one or more aircraft, Table 6 matches the NSNs in this study to their respective explanatory variable, identified by aircraft type.

NSN	POSSIBLE EXPLANATORY VARIABLES
7R 6610-00-133-7868	EA-6B, F-14, S-3B, A-6E
7R 5841-01-120-4885	F/A-18
7R 6610-01-088-2352	EA-6B, S-3B, A-6E
7R 5895-01-162-9449	EA-6B, F-14, F/A-18, SH-3H, SH-60F, HH-60H
7R 6615-00-182-7733	EA-6B, E2-C, SH-3H
7R 5895-01-040-1531	EA-6B, A-6E, F-14, SH-3H

Table 6. Aircraft/NSN Assignment.

b. Indicator Variables

Carrier deployment can be used as an indicator variable in the model. Because deployment of a carrier influences the demand for aircraft spare parts, indicator variables account for this influence. With their inclusion in the model, the general form of a regression equation becomes:

$$C_t = \alpha + \beta_0 (Flying\ Hours)_t + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} \qquad (4.9)$$

where: X_{1t}= 1 if the first carrier is deployed during month t and 0 otherwise; X_{2t}= 1 if the second carrier is deployed during month t and 0 otherwise; and X_{3t}= 1 if the third carrier is deployed during month t and 0 otherwise.

Carrier deployment history was obtained from the Supply Department of the Pacific Fleet Naval Air Forces. These deployment dates are shown in Table 7.

CARRIER	DEPLOYMENT DATES	YOKOSUKA REQUISITION POINT OF ENTRY DATES
USS ABRAHAM LINCOLN (CVN-72)	15 June 1993 - 15 December 1993	21 June 1993 - 01 December 1993
USS INDEPENDENCE (CV-62)	17 November 1993 - 17 March 1994	17 November 1993 - 17 March 1994
USS CARL VINSON (CVN-70)	17 February 1994 - 17 August 1994	21 February 1994 - 06 August 1994

Table 7. Carrier Deployment Schedule.

Flying hours for the CONUS-based carriers, LINCOLN and VINSON, covered their respective Yokosuka POE requisition dates. Flying hours for the Yokosuka-based INDEPENDENCE covered the entire twelve month period, including deployed and non-deployed time frames. Because the INDEPENDENCE is the Navy's forward deployed carrier, it is always in a deployed state of readiness (OPNAV 4614.1F, 1992). However, the indicator variable "1" is used in this model only during its deployed period because flying hours increase substantially during deployment.

c. ***Lagged Variables***

Lagged variables are used in the model when the influence of the independent variable does not manifest itself on the dependent variable until a certain time period has elapsed. Lags can influence one period or be distributed over time. With distributed lags, the influence of the independent variable is distributed on the dependent variable over more than one time period. With a simple lag, the independent variable's influence occurs for one time period only. Simple lags are used for simplicity in this model. With the inclusion of lagged variables, the general regression equation becomes:

$$C_t = \alpha + \beta_0(Flying\ Hours)_{(t-n)} + \beta_1 X_{1(t-n)} + \beta_2 X_{2(t-n)} + \beta_3 X_{3(t-n)} \quad (4.10)$$

where n is the number of months lagged.

C. RESULTS

MINITAB statistical software is used in the analysis to determine regression coefficients. This process involves examining possible coefficients as well as the statistical significance of the output. In marginal value forecast determinations, the item's net unit price is used for P, the price variable. Calculation of specific stockout costs is beyond the scope of this study. For illustration purposes, a stockout cost of $10,000 is assigned to each item. Specific forecast results are provided in Appendix D.

1. 7R 6615-00-182-7733, Displacement Gyroscope

The best regression fit is:

$$C_t = -2.98 + 0.0349\ (EA\text{-}6B\ HRS)_t \quad (4.11)$$

Table 8 summarizes the statistics for the regression:

PREDICTOR	**t-RATIO**
CONSTANT	-0.84
EA-6B HRS	3.01
r^2 (adj)	42.3%
F-Ratio	9.05 Significant at .013 Level

Table 8. Causal Statistical Summary for 7R 6615-00-182-7733.

The constant can be removed from the equation because it is not statistically significant. The causal forecast equation then becomes:

$$C_t = 0.0260\ (EA\text{-}6B\ HRS)_t \qquad (4.12)$$

which is statistically significant. In other words, there are 2.6 requisitions submitted for these Displacement Gyroscopes from the carriers to the Yokosuka SHORCAL for every 100 hours the EA-6B aircraft flies. The absence of indicator variables indicates that carrier deployment does not affect off-ship demand. This could mean that the internal logistics support system, i.e., AVCAL provisioning and the maintenance capability of these carriers, influences off-ship demand.

2. 7R 5895-01-040-1531, Electronic Communication Case

The best regression fit is:

$$C_t = 0.00 + 1.25(CVN\text{-}70)_t \qquad (4.13)$$

where indicator variable *CVN-70* is equal to 1 when this carrier is deployed and 0 otherwise. Table 9 summarizes the statistics for the regression:

PREDICTOR	**t-RATIO**
CONSTANT	0.00
CVN-70	3.89
r^2 (adj)	56.3 %
F-Ratio	15.15 Significant at .003 Level

Table 9. Causal Statistical Summary for 7R 5895-01-040-1531.

Removing the constant yields the following equation for computing the causal forecast:

$$C_t = 1.25(CVN\text{-}70)_t \tag{4.14}$$

which is statistically significant. Examination of the demand history for this item reveals why flying hours do not correlate with demand, and why the deployment of one carrrier, the CARL VINSON (CVN-70), influences off-ship demand for the SHORCAL. There are two demands in each of the months of March and April, one demand in May and zero in the other months. The reason for this low demand is that the failure rate of this item is determined to be one failure for every 25,000 hours of use (Marcinkus, October/November, 1994). Since this is much less than the flying hours observed, more data points need to be obtained to adequately analyze the correlation between flying hours and demand.

The months of demand correspond to the CARL VINSON's deployment period, February through June. Equation 4.14 indicates that there are 1.25 monthly demands submitted during that carrier's deployment to the Yokosuka SHORCAL for these Electronic Communication Cases. The internal logistics system supporting the item on this carrier must be different than that of the other two carriers.

3. 7R 6610-01-088-2352, Attitude Indicator

The best regression fit is :

$$C_t = 1.39 + 0.00939\ (S\text{-}3B\ HRS)_t \tag{4.15}$$

Table 10 summarizes the statistics for the regression:

PREDICTOR	t-RATIO
CONSTANT	0.77
S-3B HRS	2.48
r^2 (adj)	32.0 %
F-Ratio	6.17 Significant at .032 Level

Table 10. Causal Statistical Summary for 7R 6610-01-088-2352.

Removing the constant yields the following forecast equation:

$$C_t = 0.0121\ (S\text{-}3B\ HRS)_t \qquad (4.16)$$

which is statistically significant. S-3B flying hours are used to compute the forecast. Equation 4.16 indicates that there are 1.2 carrier demands per month for every 100 S-3B flying hours.

4. 7R 5841-01-120-4885, Height Indicator

The best regression fit is:

$$C_t = 0.84 + 0.00211\ (F/A\text{-}18)_{(t\ 1)} \qquad (4.17)$$

The F/A-18 is the only aircraft type in which this item is installed. Flying hours are lagged one month, indicating that aircraft usage does not affect demand on the Yokosuka SHORCAL until one month has elapsed. Table 11 summarizes the statistics for the regression:

PREDICTOR	t-RATIO
CONSTANT	0.58
F/A-18	1.57
r^2 (adj)	12.8 %
F-Ratio	2.47 Significant at .15 Level

Table 11. Causal Statistical Summary for 7R 5841-01-120-4885.

Equation 4.17 is not statistically significant. However, upon removing the constant, the causal forecast Equation becomes:

$$C_t = 0.00279\,(F/A-18\,)_{(t\ 1)} \tag{4.18}$$

which is highly significant. Equation 4.18 indicates that there are 2.8 carrier requisitions submitted for this item to the Yokosuka SHORCAL for every 1000 hours F/A-18 aircraft are flown.

5. 7R 5895-01-162-9449, Radio Receiver and 7R 6610-00-133-7868, Counting Indicator

The causal models do not produce statistically significant regression fits for the demand for these items. The monthly forecast is determined using the time-series method or the marginal value method for each item's total demand.

6. 7R 5826-00-117-4629, Bearing Indicator

This item has no carrier demand and the causal method is not used.

D. COMPARISONS

Forecasts of carrier demand residuals using time-series and the marginal value method are added to the causal forecasts of carrier demand. These forecasts are then added to forecasts for non-carrier demand to determine the final forecasts. This provides two forecasts for each item to compare against results obtained using the current Yokosuka forecasting model. The process for the seven NSNs is outlined in Appendix D. The objective of this process is to find the forecast which results in the lowest MAD. MAD values by item for each forecasting method are summarized in Table 12. The alternate model demonstrates lower forecast error than the current Yokosuka model for four of the seven NSNs.

NSN	CAUSAL/ TIME SERIES	CAUSAL/ MARGINAL	CURRENT MODEL
7R 6610-00-133-7868	1.083	3.000	1.250
7R 6615-00-182-7733	3.858	3.590	4.917
7R 5895-01-040-1531	2.646	3.125	2.083
7R 6610-01-088-2352	1.886	1.886	1.875
7R 5841-01-120-4885	2.114	2.108	1.769
7R 5895-01-162-9449	3.167	4.333	3.278
7R 5826-00-117-4629	1.583	2.250	1.681

Table 12. MAD Values of Forecast Results.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The Navy's investment in spare parts inventories grew steadily in the 1980's. Recent initiatives, such as the Defense Management Review Decision and the Department of Defense Inventory Reduction Plan, mandate reducing inventory investment. It is therefore important in the current declining budget scenario to strive to develop alternate methods of demand forecasting and inventory management that meet performance goals, while maintaining prescribed force readiness. This thesis focuses on a Navy intermediate level inventory, the Shorebased Consolidated Allowance List (SHORCAL), in Yokosuka Japan. The SHORCAL inventory supports Navy and Marine Corps aviation requirements in the Western Pacific and Indian Ocean theaters. This thesis proposes an alternate demand forecasting model for the SHORCAL.

Chapter II describes the SHORCAL inventory. The SHORCAL concept and range of customers is presented. Supply performance goals for the SHORCAL are explained and compared to actual performance. In particular, SHORCAL inventory effectiveness goals were not met for the period analyzed in this study, July 1993 through June 1994.

Chapter III describes the existing SHORCAL forecasting model and introduces an alternate model. The existing model is a time-series smoothing model which averages monthly demand over a twelve month period. The alternate model combines a causal method for demand originating from aircraft carrier customers with either a time-series method or marginal value method for aircraft carrier causal residuals and non-carrier customer demand.

The alternate forecasting model is evaluated using historical demand data from seven Aviation Depot Level Repairable items (AVDLRs) in Chapter IV. Results are compared against the Yokosuka model. The alternate model demonstrates smaller forecast error for four of the seven items analyzed in this study.

B. CONCLUSIONS

The alternate forecasting model demonstrates the influence of aircraft flying hours and carrier deployment on carrier demand. Additionally, if stockout costs can be ascertained and minimized, an improved forecast can be derived.

This study shows lower forecast error can be achieved for the Yokosuka SHORCAL through the use of this simple alternate model. Lower forecast error can result in lower inventory cost without impacting readiness.

C. RECOMMENDATIONS

Additional research is needed to determine the predictive capability of the model. A limitation in this study is that, at the present time, only about twelve months of SHORCAL historical demand data is retained by FISC Yokosuka and the Naval Aviation Supply Office. The smaller the number of data points, the lower the confidence that the regression model accurately represents reality. Data should be retained for a longer period to provide more data points for the analysis. As more data points are included, the prediction interval can narrow and higher confidence in the forecast can result. Thus, the regression line can more closely represent demand for spare parts.

In the case of the marginal value method, additional data points can generate a more accurate estimate of each item's stockout probability, thereby increasing the accuracy of the prediction.

Further research is needed in quantifying stockout costs for the marginal value method. This involves determining the mission criticality of each item and how much the failure of an item contributes to total aircraft grounding cost.

The timing of data availability is crucial to model application. Planned flying hours and carrier deployment schedules should be made available to model implementers ahead of time - at least one procurement lead time preceding the first future forecast period. This would allow sufficient time to reevaluate model coefficients, calculate forecasts and adjust allowances accordingly.

Future estimates of flying hours and carrier deployment schedules should be developed carefully. If actual flying hours and deployment dates deviate substantially from estimates used in forecast determination, forecast accuracy would be adversely affected.

The additional exogenous and endogenous independent variables discussed in this thesis should be quantified and tested in the causal model. If any of these additional variables are correlated to increasing demand, including them in the model could increase the accuracy of the forecast.

Additional study should also focus on the current model used to set reorder points and allowance levels for the SHORCAL. An inferior inventory model can not result in improved supply performance regardless of the accuracy of the forecast.

APPENDIX A. DATA

This appendix contains the data used in this study. A description of the data columns follows:

COLUMN NUMBER	**COLUMN TITLE**	**COLUMN DESCRIPTION**
1	UIC	Five digit Unit Identification Codes of the requesting activities. Zeros have been omitted from the beginning of codes for data manipulation within LOTUS 1 - 2- 3 spreadsheet. Appendix B contains a listing of the UICs and associated activity names.
2	Julian Date	Assigned by the requesting activity. The first digit is the last number of the year . The next three digits are the numerical day of the year.
3	Serial Number	A four digit number assigned consecutively by the requesting activity.
4	Month Ending Date	The ending date of the month of demand.

5	Total Monthly Demand Quantity	The quantity demanded in the month of demand.
6	Carrier Demand Quantity	The quantity demanded by aircraft carriers in the month of demand.
7	Non-Carrier Demand Quantity	The quantity demanded by all other activities in the month of demand.

	NSN 7R 6610-00-133-7868					
	REQUISITION NUMBER					
UIC	JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
21297	3199	1917				
21297	3209	1918	07/31/93	2	2	0
21297	3214	1917				
3362	3215	E718	8/31/93	2	2	0
			9/30/93	0	0	0
			10/31/93	0	0	0
3362	3333	1822	11/30/93	1	1	0
334	3363	9802	12/31/93	1	0	1
3362	4012	1801				
3362	4025	G744	1/31/94	2	2	0
3362	4034	G133				
3362	4038	1726				
3362	4042	G198				
20993	4053	1931				
20993	4055	1935	2/28/94	5	5	0
20993	4066	1935				
20993	4074	1942				
20993	4075	1937				
20993	4075	1950				
20993	4078	1937				
20993	4089	1933	3/31/94	6	6	0
20993	4106	1933				
20993	4119	1935	4/30/94	2	2	0
20993	4139	1941				
20993	4145	1810	5/31/94	2	2	0
20993	4154	1939				
20993	4160	1943				
20993	4167	1945	6/30/94	3	3	0

NSN
7R 5895-01-162-9449

UIC	REQUISITION NUMBER JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
9136	3181	1702				
3362	3184	1992				
3362	3184	1993				
9136	3195	1995				
9112	3201	1703				
21297	3207	1918				
9136	3211	1701				
9136	3211	1704	7/31/93	8	3	5
21297	3216	1940				
9112	3218	1702				
9136	3222	1712				
21297	3223	1939				
62507	3228	7621				
62507	3231	3R50				
9112	3237	1704				
21297	3241	1810	8/31/93	8	3	5
21297	3244	1925				
62507	3245	3R50				
9112	3250	1700				
21297	3250	1918				
21297	3251	1912				
21297	3251	1914				
3362	3253	1821				
62507	3258	3R57				
62507	3267	7623				
61577	3271	D418	9/30/93	10	5	5
9136	3274	1706				
3362	3278	1837				
3362	3281	1835				
3362	3282	1813				
9136	3287	1706				
9112	3291	1742				
3362	3293	1809				
9136	3300	1701				
7202	3302	1933				
21297	3302	1916	10/31/93	10	5	5
62507	3309	D606				
9136	3320	1708				
9112	3321	1712				
9112	3330	1721				
68212	3334	1700	11/30/93	5	0	5
55616	3335	2117				
7202	3344	1907				
9112	3347	1705				
3362	3349	1830				
3362	3349	1824				
3362	3349	1822				
3362	3349	1811				
9136	3349	1705				
3362	3354	1844	12/31/93	9	5	4
9136	4005	1714				
9112	4006	1705				
9112	4018	1736				
3362	4023	1806	1/31/94	4	1	3
20748	4035	1903				
62507	4038	7622				
63126	4039	CJ00				
9112	4040	1702				
9112	4042	1706				
236	4048	C100				
63126	4049	CJ03				
20993	4051	1928				
3362	4053	1809				
3362	4056	1804				
9112	4059	1709	2/28/94	11	3	8
3362	4063	1805				

	NSN 7R 5895-01-162-9449					
	REQUISITION NUMBER		MONTH	TOTAL MONTHLY	CARRIER	NON-CARRIER
UIC	JULIAN DATE	SERIAL NUMBER	ENDING DATE	DEMAND QUANTITY	DEMAND QUANTITY	DEMAND QUANTITY
20993	4068	1937				
3362	4073	1806				
9136	4084	1703				
20993	4086	1932				
20993	4087	1928				
7198	4088	1935				
7198	4088	1934	3/31/94	8	5	3
20725	4091	1994				
20725	4091	1995				
9136	4095	1707				
20993	4101	D153				
20993	4103	D146				
20993	4113	D104				
62507	4119	7625				
207	4119	FX03	4/30/94	8	3	5
61577	4131	D412				
9136	4138	1714				
9112	4144	1700				
3362	4145	1803	5/31/94	4	1	3
9112	4152	1705				
9112	4154	1702				
63042	4156	BH99				
9112	4159	1711				
63042	4159	BH06				
20993	4159	1931				
9808	4160	4L00				
9136	4160	1701				
20993	4161	1929				
63042	4162	BH02				
63042	4162	BH01				
9112	4164	1733				
3362	4166	1808				
65923	4166	18B7				
9112	4167	1700				
61577	4167	D413				
68753	4174	A087				
9112	4175	1711				
20633	4181	1901	6/30/94	19	3	16

	NSN 7R 5841-01-120-4885					
	REQUISITION NUMBER					
UIC	JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
3362	3184	1969				
3362	3184	1970				
3362	3188	G319				
21297	3201	1918				
21297	3203	1913				
3362	3208	1801	7/31/93	6	6	0
3362	3238	1819				
3362	3238	1819	8/31/93	2	2	0
3362	3245	G320				
9112	3258	1707				
9112	3258	1708				
9112	3258	1706	9/30/93	4	1	3
21297	3280	1927	10/31/93	1	1	0
21297	3309	1940				
21297	3313	1925				
3362	3323	1804				
3362	3327	1827	11/30/93	4	4	0
3362	3343	G306				
3362	3344	1802				
3362	3345	1757	12/31/93	3	3	0
			1/31/94	0	0	0
3362	4051	1916	2/28/94	1	1	0
9112	4060	1707				
20993	4061	1935				
20993	4062	1932				
20993	4064	1939				
20993	4069	1933				
20993	4074	1927				
20993	4083	1926				
20993	4085	1930				
20993	4087	1926	3/31/94	9	8	1
20993	4108	1929				
9112	4116	1706				
9112	4118	1709	4/30/94	3	1	2
9112	4122	1702				
3362	4138	1825				
20993	4141	1946				
20993	4142	1946				
20993	4151	1928	5/31/94	5	4	1
20993	4152	1955				
20993	4156	1942				
3362	4166	1803				
20993	4168	G096				
20993	4178	1937				
20993	4181	1930	6/30/94	6	6	0

NSN
7R 5895-01-040-1531

UIC	REQUISITION NUMBER JULIAN DATE	REQUISITION NUMBER SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
			7/31/93	0	0	0
204	3222	F601				
21048	3223	D087				
9136	3228	1717				
204	3229	B302	8/31/93	4	0	4
68316	3250	AQ77				
21048	3250	D094				
21346	3251	D465				
21447	3261	D703	9/30/93	4	0	4
5838	3275	W056				
21387	3279	W002				
68316	3302	AQ87				
68316	3302	AQ86	10/31/93	4	0	4
20144	3312	6023	11/30/93	1	0	1
20836	3336	W054				
21452	3365	D023				
7813	3365	D050	12/31/93	3	0	3
21345	4010	D170				
21452	4016	D028				
20154	4028	D006	1/31/94	3	0	3
21437	4032	D155				
21105	4040	D064				
20599	4055	W067	2/28/94	3	0	3
21047	4061	1805				
20748	4069	1994				
20748	4070	1996				
21108	4071	D101				
7196	4075	W003				
20993	4076	D141				
21197	4079	D054				
3362	4084	1801				
62507	4085	7639				
20633	4088	1936	3/31/94	10	2	8
5833	4091	D080				
3362	4094	1813				
4696	4105	388				
20748	4108	1995				
3362	4111	1826				
21110	4112	D135				
21639	4120	D038	4/30/94	7	2	5
3362	4121	1803				
7182	4128	D070				
5840	4132	D052				
9136	4132	1990				
20633	4136	1904				
9136	4143	1991	5/31/94	6	1	5
			6/30/94	0	0	0

	NSN 7R 6610-01-088-2352					
	REQUISITION NUMBER					
UIC	JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
3362	3184	1961				
9112	3194	1722				
3362	3204	1804				
3362	3206	1803				
21297	3208	78				
3362	3211	1807				
3362	3211	1809	7/31/93	7	6	1
21297	3221	1912				
3362	3231	1816				
3362	3231	1819				
3362	3235	1905				
3362	3235	1906	8/31/93	5	5	0
21297	3244	1920				
21297	3246	1911				
9112	3248	1911				
3362	3258	1808				
21297	3265	1927				
3362	3267	1807				
21297	3268	1913				
3362	3270	1791	9/30/93	8	7	1
3362	3274	1825				
3362	3274	1868				
3362	3274	1813				
21297	3275	1954				
21297	3276	1926				
3362	3276	1805				
3362	3278	1840				
3362	3278	1840				
3362	3279	1819				
3362	3281	1801				
9112	3292	1703				
9112	3298	1705	10/31/93	12	10	2
6632	3309	1824				
21297	3324	1925				
3362	3334	1809	11/30/93	3	2	1
3362	3339	1811				
9112	3343	1706				
3362	3345	1814				
3362	3354	1826				
3362	3356	1810				
3362	3356	1813				
3362	3357	1813				
3362	3358	1813	12/31/93	8	7	1
3362	4015	1803	1/31/94	1	1	0
9112	4040	1705				
9112	4040	1704				
9112	4049	1732				
3362	4051	1808				
3362	4051	1807				
3362	4056	1801				
3362	4059	1801	2/28/94	7	4	3
9112	4061	1705				
20993	4062	1928				
3362	4062	1954				
3362	4062	1955				
3362	4064	18036				
20993	4070	1926				
20993	4075	1943				
20993	4075	1933				
20993	4076	1932	3/31/94	9	8	1
61577	4096	G511				
3362	4096	1814				
20993	4097	1934				
3362	4098	1810				
3362	4111	1825				

NSN
7R 6610-01-088-2352

UIC	REQUISITION NUMBER		MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
	JULIAN DATE	SERIAL NUMBER				
20993	4113	1942				
3662	4119	1823	4/30/94	7	6	1
9112	4137	1703				
20993	4137	1931				
20993	4139	1934				
20993	4140	1926				
20993	4140	1934				
3362	4149	1804				
3362	4150	1815	5/31/94	7	6	1
20993	4159	1932				
9112	4166	1712				
20993	4167	1926				
20993	4167	1927				
3362	4176	1811				
3363	4179	1701				
3363	4179	1730	6/30/94	7	6	1

NSN 7R 5826-01-117-4629						
	REQUISITION NUMBER					
UIC	JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
68539	3182	E005				
68539	3183	E007				
68212	3189	81				
68212	3189	82				
68212	3190	475				
68212	3190	476				
68212	3190	477				
68212	3190	496				
68212	3190	512				
68212	3202	DP47	7/31/93	10	0	10
68212	3225	25				
68212	3229	35				
68212	3229	36				
68212	3232	10				
68539	3238	E019				
62254	3242	4	8/31/93	6	0	6
68212	3253	707				
68539	3253	E002				
68212	3257	705				
68212	3260	700				
68212	3260	701				
68212	3262	701				
68539	3265	E006	9/30/93	7	0	7
68539	3279	E008				
68212	3283	700				
68212	3285	702				
68212	3286	701				
68212	3289	G578				
68212	3301	702				
68212	3301	704				
68539	3302	E012	10/31/93	8	0	8
68212	3309	701				
68212	3309	702				
68212	3313	700				
68539	3313	E013				
68539	3313	E073				
68212	3313	G516	11/30/93	6	0	6
68212	3343	703				
68212	3347	701				
68212	3350	701				
68212	3351	701				
68212	3352	700				
68212	3360	700	12/31/93	6	0	6
68212	4004	700				
68539	4004	E003				
68539	4004	E002				
68539	4006	E009				
68539	4006	E008				
68212	4012	703				
68539	4014	E012				
68539	4019	E013				
68539	4028	E017				
68539	4028	E015	1/31/94	10	0	10
68212	4038	716				
68212	4038	708				
68212	4038	707				
68212	4041	704				
68212	4043	704				
68212	4047	G532				
68212	4057	GP63	2/28/94	7	0	7
68212	4086	703	3/31/94	1	0	1
334	4098	9804				
68212	4102	706				
68212	4103	DP72				
68212	4103	701				

NSN
7R 5826-01-117-4629

UIC	REQUISITION NUMBER JULIAN DATE	SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
68212	4104	703				
68212	4110	700				
68212	4111	798				
68212	4112	703				
68212	4118	GP21	4/30/94	9	0	9
68212	4121	GP23				
68212	4122	701				
334	4123	9803				
68212	4123	707				
68212	4135	700				
68212	4135	701				
68539	4147	E008				
68212	4148	702	5/31/94	8	0	8
68539	4152	E011				
68212	4156	700				
68212	4160	701				
68212	4160	700				
68539	4175	E005				
68539	4178	E006				
68539	4178	E007	6/30/94	7	0	7

NSN
7R 6615-00-182-7733

UIC	REQUISITION NUMBER JULIAN DATE	REQUISITION NUMBER SERIAL NUMBER	MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
3362	3202	1802				
21297	3205	1920				
21297	3207	1916				
21297	3209	1921				
21297	3210	1924	7/31/94	5	5	0
21297	3215	1919				
21297	3217	1811				
3362	3217	1824				
3362	3217	1825				
21297	3217	1919				
21297	3217	1916				
21297	3217	1802				
21297	3217	1810				
3362	3217	1812				
21297	3220	1914				
52708	3223	AR02				
3362	3224	1810				
3362	3225	1816				
3362	3229	1977				
21297	3235	1922				
246	3236	9358				
21297	3237	1913				
21297	3240	1918				
3362	3243	1803	8/31/93	19	17	2
21297	3244	1921				
3362	3245	1813				
21297	3246	1933				
21297	3248	1918				
21297	3252	1926				
21297	3261	1927				
21297	3262	1927				
21297	3263	1919				
21297	3263	G835				
3362	3266	1812				
21297	3266	1913				
3362	3269	1765	9/30/93	12	12	0
3362	3274	1855				
21297	3274	1880				
275	3275	GB05				
21297	3276	1925				
3362	3277	1811				
3362	3277	1810				
21297	3278	1958				
21297	3278	1931				
21297	3278	G974				
21297	3281	1927				
3362	3284	1803				
3362	3284	1719				
21297	3285	1915				
3362	3289	AR17				
3362	3292	1805				
3362	3299	G687				
21297	3300	1936				
3362	3304	1802	10/31/93	18	17	1
21437	3306	AU42				
21437	3306	AU43				
3362	3316	G603				
3362	3329	1801				
3362	3329	1848				
3362	3329	1849	11/30/93	6	4	2
3362	3341	1814				
188	3343	6711				
3362	3343	1803				
3362	3350	1816				
62507	3350	7626				

NSN
7R 6615-00-182-7733

UIC	REQUISITION NUMBER		MONTH ENDING DATE	TOTAL MONTHLY DEMAND QUANTITY	CARRIER DEMAND QUANTITY	NON-CARRIER DEMAND QUANTITY
	JULIAN DATE	SERIAL NUMBER				
21437	3363	AU49	12/31/93	6	3	3
3362	4003	1817				
421	4011	5008				
3362	4016	1821				
3362	4020	1833				
3362	4020	1834				
3362	4021	1821	01/31/94	6	5	1
			2/28/94	0	0	0
188	4067	6822				
188	4069	6718	3/31/94	2	0	2
			4/30/94	0	0	0
20993	4124	1954				
20993	4124	1942				
20993	4124	1945				
20993	4125	1929				
20993	4133	1928				
20993	4138	1928				
20993	4143	1940				
20993	4150	1931	5/31/94	8	8	0
3362	4153	1817				
20993	4153	1929				
20993	4154	1927				
20993	4162	1934				
20993	4168	1929				
20993	4170	1928				
20993	4170	1932				
20993	4171	1936				
20993	4172	1947				
20993	4176	1928				
3362	4178	1815				
3363	4179	1704	6/30/94	12	12	0

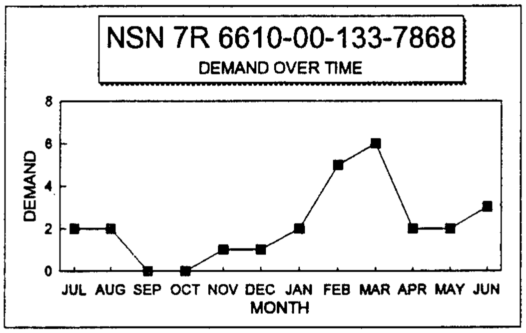
APPENDIX B. UNIT IDENTIFICATION CODES AND ACTIVITIES

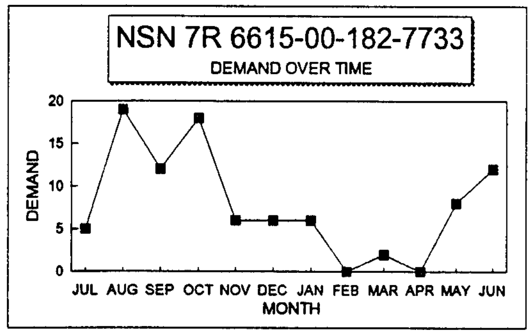
00158	NAVAL AIR STATION WILLOW GROVE
00204	NAVAL AIR STATION PENSACOLA
00207	NAVAL AIR STATION JACKSONVILLE
00215	NAVAL AIR STATION DALLAS
00236	NAVAL AIR STATION ALAMEDA
00334	NAVAL AIR STATION BARBER'S POINT
00421	NAWC PATUXENT RIVER
03362	USS INDEPENDENCE (CV-62)
03363	USS KITTY HAWK (CV-63)
04648	USS SAMUEL GOMPERS (AD 37)
04696	USS HOLLAND (AS-32)
05838	USS KILAUHEA (AE-26)
05840	USS BLUE RIDGE (LCC-19)
07182	USS DUBUQUE (LPD-8)
07183	USS DENVER (LPD-9)
07196	USS NASHVILLE (LPD-13)
07198	USS TRIPOLI (LPH-10)
07202	USS NEW ORLEANS (LPH-11)
09112	MARINE AIR LOGISTICS SQUADRON 12
09114	MARINE AIR LOGISTICS SQUADRON 14
09136	MARINE AIR LOGISTICS SQUADRON 36
09808	MARINE AIR LOGISTICS SQUADRON 39
20144	USS ORTOLAN (ASR-12)
20599	USS JOHN YOUNG (DD-973)
20633	USS BELLEAU WOOD (LHA-3)
20725	USS NASSAU (LHA-4)
20748	USS PELELUI (LHA-5)

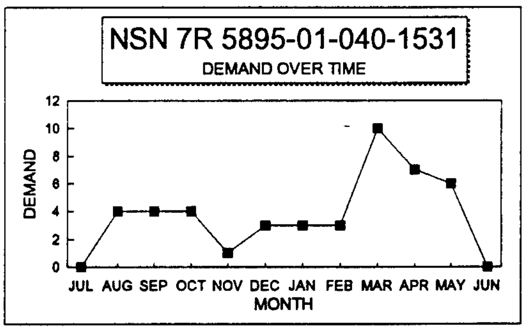
20836	USS DEYO (DD-989)
20993	USS CARL VINSON (CVN-70)
21044	USS TENNESSEE (SSBN-734)
21047	USS ACADIA (AD-42)
21048	USS WILLAMETTE (AO-180)
21055	USS REID (FFG-30)
21105	USS CURTS (FFG-38)
21108	USS MCCLUSKY (FFG-41)
21110	USS THATCH (FFG-43)
21197	USS DE WERT (FFG-45)
21297	USS ABRAHAM LINCOLN (CVN-72)
21345	USS BUNKER HILL (CG-52)
21346	USS MOBILE BAY (CG-53)
21387	USS ANTIETAM (CG-54)
21437	USS CALLAGHAN (DDG-994)
21447	USS PRINCETON (CG-59)
21452	USS COMSTOCK (LSD-45)
21639	USS GERMANTOWN (LSD-42)
55616	MARINE HELICOPTER SQUADRON HMX-1
57082	MARINE AIR LOGISTICS SQUADRON 13
60259	NAVAL AIR STATION MIRAMAR
61577	NAVAL AIR STATION GUAM
62507	NAF ATSUGI
62995	NAVAL AIR STATION SIGONELLA
63042	NAVAL AIR STATION LEMOORE
63126	PMTC PT MUGU
65923	MARINE CORPS AIR STATION, CHERRY POINT
68212	NAVAL AIR STATION MISAWA
68316	SSF NEW LONDON CT

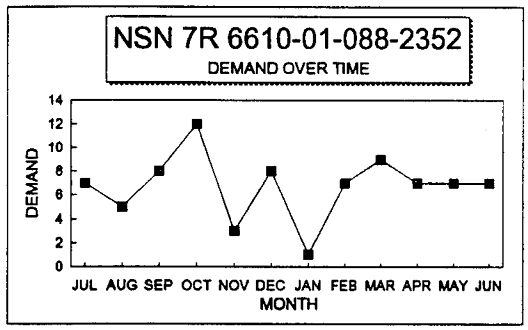
68539	NSF DIEGO GARCIA
68753	NAVAL AIR REPAIR ACTIVITY DET, SINGAPORE

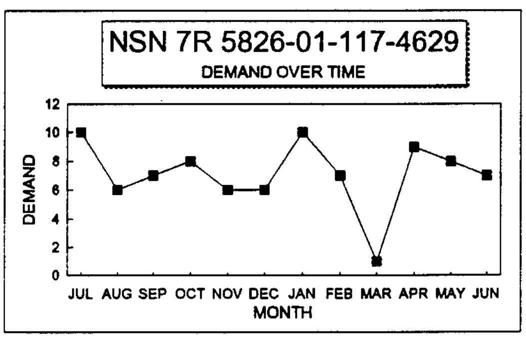
APPENDIX C. DEMAND BY ITEM JULY 1993 - JUNE 1994

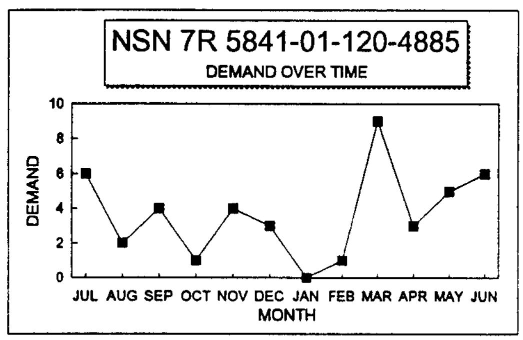


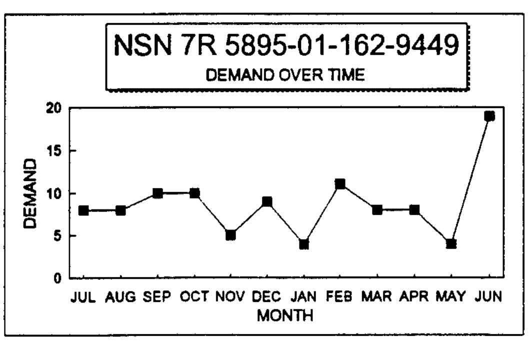












APPENDIX D. FORECAST RESULTS

This appendix contains results of forecasts for the seven NSNs obtained using the alternate model. These results are compared to forecasts obtained using the current forecasting model.

NSN 7R 6610-00-133-7868
FINAL FORECASTS

MONTH	DEMAND	CARRIER & NON-CARR. TIME SERIES	ABS DEV	CARRIER & NON-CARRIER MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	2	2.000	0.000	5.000	3.000	2	0.167
AUG	2	2.000	0.000	5.000	3.000	2	0.167
SEP	0	2.000	2.000	5.000	5.000	2	2.167
OCT	0	0.000	0.000	5.000	5.000	2	2.167
NOV	1	0.000	1.000	5.000	4.000	2	1.167
DEC	1	1.000	0.000	5.000	4.000	2	1.167
JAN 1994	2	1.000	1.000	5.000	3.000	2	0.167
FEB	5	2.000	3.000	5.000	0.000	2	2.833
MAR	6	5.000	1.000	5.000	1.000	2	3.833
APR	2	6.000	4.000	5.000	3.000	2	0.167
MAY	2	2.000	0.000	5.000	3.000	2	0.167
JUN	3	2.000	1.000	5.000	2.000	2	0.833
		MAD =	1.0833		3.0000		1.2500

NSN 7R 6610-00-133-7868 MARGINAL METHOD		p(M>Q) = 843/10000 = 0.084			
BEST FORECAST	CARRIER AND NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	0	2	0.1667	0.1667	0.8333
	1	2	0.1667	0.3333	0.6667
	2	5	0.4167	0.7500	0.2500
	3	1	0.0833	0.8333	0.1667
→	5	1	0.0833	0.9167	0.0833
	6	1	0.0833	1.0000	0.0000
		12	1		

FORECASTS FOR 7R 6610-00-133-7868
CARRIER AND NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 1 EWMA FORECAST	ABS DEV	LAST PRD DEMAND FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	2	2.000		2.000			
AUG	2	2.000	0.000	2.000	0.000		
SEP	0	2.000	2.000	2.000	2.000		
OCT	0	0.000	0.000	0.000	0.000	1.333	1.333
NOV	1	0.000	1.000	0.000	1.000	0.667	0.333
DEC	1	1.000	0.000	1.000	0.000	0.333	0.667
JAN 1994	2	1.000	1.000	1.000	1.000	0.667	1.333
FEB	5	2.000	3.000	2.000	3.000	1.333	3.667
MAR	6	5.000	1.000	5.000	1.000	2.667	3.333
APR	2	6.000	4.000	6.000	4.000	4.333	2.333
MAY	2	2.000	0.000	2.000	0.000	4.333	2.333
JUN	3	2.000	1.000	2.000	1.000	3.333	0.333
		MAD=	1.1818		1.1818		1.7407

MONTH	DEMAND	ALPHA = 1 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	2	2.000	0.100	2.100	
AUG	2	2.000	0.095	2.095	0.095
SEP	0	2.000	0.090	2.090	2.090
OCT	0	0.000	-0.014	-0.014	0.014
NOV	1	0.000	-0.014	-0.014	1.014
DEC	1	1.000	0.037	1.037	0.037
JAN 1994	2	1.000	0.035	1.035	0.965
FEB	5	2.000	0.084	2.084	2.916
MAR	6	5.000	0.229	5.229	0.771
APR	2	6.000	0.268	6.268	4.268
MAY	2	2.000	0.054	2.054	0.054
JUN	3	2.000	0.052	2.052	0.948
				MAD=	1.1975

NSN 7R 5895-01-040-1531
FINAL FORECASTS

MONTH	DEMAND	CAUSAL FORECAST	NON-CARR. TIME SERIES	RESID. TIME SERIES	NON-CARRIER MARGINAL	CARRIER RESIDUAL MARGINAL	TOTAL CAUSAL & TIME SERIES	ABS DEV	TOTAL CAUSAL & MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	0	0.000	0.000	0.000	5.000	1.000	0	0.000	6	6.000	4	3.750
AUG	4	0.000	4.000	0.000	5.000	1.000	4	0.000	6	2.000	4	0.250
SEP	4	0.000	4.000	0.000	5.000	1.000	4	0.000	6	2.000	4	0.250
OCT	4	0.000	1.333	0.000	5.000	1.000	1	2.667	6	2.000	4	0.250
NOV	1	0.000	3.000	0.000	5.000	1.000	3	2.000	6	5.000	4	2.750
DEC	3	0.000	0.000	0.000	5.000	1.000	0	3.000	6	3.000	4	0.750
JAN 1994	3	0.000	0.333	0.000	5.000	1.000	0	2.667	6	3.000	4	0.750
FEB	3	0.000	0.667	0.000	5.000	1.000	1	2.333	6	3.000	4	0.750
MAR	10	1.250	5.000	0.000	5.000	1.000	6	3.750	7	2.750	4	6.250
APR	7	1.250	0.333	0.750	5.000	1.000	2	4.667	7	0.250	4	3.250
MAY	6	1.250	0.333	0.750	5.000	1.000	2	3.667	7	1.250	4	2.250
JUN	0	1.250	6.000	-0.250	5.000	1.000	7	7.000	7	7.250	4	3.750
							MAD =	2.6459		3.1250		2.0833

NSN 7R 5895-01-040-1531 MARGINAL METHOD			p(M>Q) = 1040/10000 = 0.104		
BEST FORECAST	CARRIER RESIDUAL	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	-1	1	0.0833	0.0833	0.9167
	0	9	0.7500	0.8333	0.1667
→	1	2	0.1667	1.0000	0.0000
		12	1		

BEST FORECAST	NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	0	2	0.1667	0.1667	0.8333
	1	1	0.0833	0.2500	0.7500
	3	3	0.2500	0.5000	0.5000
	4	3	0.2500	0.7500	0.2500
→	5	2	0.1667	0.9167	0.0833
	8	1	0.0833	1.0000	0.0000
		12	1		

FORECASTS FOR 7R 5895-01-040-1531
CARRIER RESIDUALS

MONTH	RESIDUAL VALUES	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	0.000	0.000		0.000			
AUG	0.000	0.000	0.000	0.000	0.000		
SEPT	0.000	0.000	0.000	0.000	0.000		
OCT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NOV	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DEC	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JAN 1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FEB	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MAR	0.750	0.000	0.750	0.000	0.750	0.000	0.750
APR	0.750	0.000	0.750	0.750	0.000	0.250	0.500
MAY	-0.250	0.000	0.250	0.750	1.000	0.500	0.750
JUN	-1.250	0.000	1.250	-0.250	1.000	0.417	1.667
		MAD=	0.2727		0.2500		0.4074

MONTH	DEMAND	ALPHA = 0.05 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	0.000	0.000	0.000	0.000	
AUG	0.000	0.000	0.000	0.000	0.000
SEPT	0.000	0.000	0.000	0.000	0.000
OCT	0.000	0.000	0.000	0.000	0.000
NOV	0.000	0.000	0.000	0.000	0.000
DEC	0.000	0.000	0.000	0.000	0.000
JAN 1994	0.000	0.000	0.000	0.000	0.000
FEB	0.000	0.000	0.000	0.000	0.000
MAR	0.750	0.000	0.000	0.000	0.750
APR	0.750	0.038	0.002	0.039	0.711
MAY	-0.250	0.075	0.004	0.079	0.329
JUN	-1.250	0.062	0.003	0.065	1.315
				MAD=	0.2822

FORECASTS FOR 7R 5895-01-040-1531
NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 0.45 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	0	0.000		0.000			
AUG	4	0.000	4.000	0.000	4.000		
SEP	4	1.800	2.200	4.000	0.000		
OCT	4	2.790	1.210	4.000	0.000	2.667	1.333
NOV	1	3.335	2.335	4.000	3.000	4.000	3.000
DEC	3	2.284	0.716	1.000	2.000	3.000	0.000
JAN 1994	3	2.606	0.394	3.000	0.000	2.667	0.333
FEB	3	2.783	0.217	3.000	0.000	2.333	0.667
MAR	8	2.881	5.119	3.000	5.000	3.000	5.000
APR	5	5.184	0.184	8.000	3.000	4.667	0.333
MAY	5	5.101	0.101	5.000	0.000	5.333	0.333
JUN	0	5.056	5.056	5.000	5.000	6.000	6.000
		MAD=	1.9574		2.0000		1.8889

MONTH	DEMAND	ALPHA = 0.35 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	0	0.000	0.000	0.000	
AUG	4	0.000	0.000	0.000	4.000
SEP	4	1.400	0.070	1.470	2.530
OCT	4	2.356	0.114	2.470	1.530
NOV	1	3.005	0.141	3.146	2.146
DEC	3	2.395	0.103	2.499	0.501
JAN 1994	3	2.674	0.112	2.786	0.214
FEB	3	2.861	0.116	2.977	0.023
MAR	8	2.985	0.116	3.102	4.898
APR	5	4.816	0.202	5.018	0.018
MAY	5	5.012	0.202	5.214	0.214
JUN	0	5.139	0.198	5.337	5.337
				MAD=	1.9465

NSN 7R 6610-01-088-2352
FINAL FORECASTS

MONTH	DEMAND	CAUSAL FORECAST	NON-CARR. TIME SERIES	RESID. TIME SERIES	NON-CARRIER MARGINAL	CARRIER RESIDUAL MARGINAL	TOTAL CAUSAL & TIME SERIES	ABS DEV	TOTAL CAUSAL & MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	7	5.630	1.000	0.370	1.000	0.000	7	0.000	7	0.370	7	0.250
AUG	5	6.213	1.000	0.370	1.000	0.000	8	2.583	7	2.213	7	1.750
SEP	8	7.984	1.000	0.370	1.000	0.000	9	1.354	9	0.984	7	1.250
OCT	12	8.530	1.000	0.370	1.000	0.000	10	2.100	10	2.470	7	5.250
NOV	3	2.572	1.000	0.370	1.000	0.000	4	0.942	4	0.572	7	3.750
DEC	8	3.458	1.000	0.370	1.000	0.000	5	3.172	4	3.542	7	1.250
JAN 1994	1	3.919	1.000	0.370	1.000	0.000	5	4.289	5	3.919	7	5.750
FEB	7	3.810	1.000	0.370	1.000	0.000	5	1.820	5	2.190	7	0.250
MAR	9	4.465	1.000	0.370	1.000	0.000	6	3.165	5	3.535	7	2.250
APR	7	5.424	1.000	0.370	1.000	0.000	7	0.206	6	0.576	7	0.250
MAY	7	6.103	1.000	0.370	1.000	0.000	7	0.473	7	0.103	7	0.250
JUN	7	8.154	1.000	0.370	1.000	0.000	10	2.524	9	2.154	7	0.250
							MAD =	1.8856		1.8856		1.8750

NSN 7R 6610-01-088-2352 MARGINAL METHOD			p(M>Q) = 4070/10000 = 0.407		
BEST FORECAST	CARRIER RESIDUAL	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	-3	1	0.0909	0.0909	0.9091
	-2	1	0.0909	0.1818	0.8182
	-1	3	0.2727	0.4545	0.5455
→	0	3	0.2727	0.7273	0.2727
	1	2	0.1818	0.9091	0.0909
	4	2	0.1818	1.0909	-0.0909
		12	1.090909090909		

BEST FORECAST	NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	0	2	0.1818	0.1818	0.8182
→	1	8	0.7273	0.9091	0.0909
	2	1	0.0909	1.0000	0.0000
	3	1	0.0909	1.0909	-0.0909
		12	1.090909090909		

FORECASTS FOR 7R 6610-01-088-2352
CARRIER RESIDUALS

MONTH	RESIDUAL VALUES	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	0.370	0.370		0.370			
AUG	-1.212	0.370	1.582	0.370	1.582		
SEPT	-0.984	0.370	1.354	-1.212	0.228		
OCT	1.470	0.370	1.100	-0.984	2.454	-0.609	2.079
NOV	-0.572	0.370	0.942	1.470	2.042	-0.242	0.330
DEC	3.542	0.370	3.172	-0.572	4.114	-0.029	3.571
JAN 1994	-2.919	0.370	3.289	3.542	6.461	1.480	4.399
FEB	0.190	0.370	0.180	-2.919	3.109	0.017	0.173
MAR	3.535	0.370	3.165	0.190	3.345	0.271	3.264
APR	0.576	0.370	0.206	3.535	2.959	0.268	0.308
MAY	-0.103	0.370	0.473	0.576	0.680	1.434	1.537
JUNE	-2.154	0.370	2.524	-0.103	2.051	1.336	3.490
		MAD=	1.6352		2.6385		2.1278

MONTH	RESIDUAL VALUES	ALPHA = 0.05 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	0.370	0.370	0.018	0.388	
AUG	-1.212	0.387	0.018	0.406	1.618
SEPT	-0.984	0.325	0.014	0.339	1.324
OCT	1.470	0.273	0.011	0.284	1.186
NOV	-0.572	0.344	0.014	0.358	0.930
DEC	3.542	0.311	0.012	0.323	3.219
JAN 1994	-2.919	0.484	0.020	0.504	3.423
FEB	0.190	0.332	0.011	0.344	0.154
MAR	3.535	0.336	0.011	0.347	3.188
APR	0.576	0.506	0.019	0.525	0.051
MAY	-0.103	0.528	0.019	0.546	0.650
JUNE	-2.154	0.514	0.017	0.531	2.685
				MAD=	1.6752

FORECASTS FOR 7R 6610-01-088-2352
CARRIER AND NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	7	7.000		7.000			
1993	5	7.000	2.000	7.000	2.000		
SEPT	8	7.000	1.000	5.000	3.000		
OCT	12	7.000	5.000	8.000	4.000	6.667	5.333
NOV	3	7.000	4.000	12.000	9.000	8.333	5.333
DEC	8	7.000	1.000	3.000	5.000	7.667	0.333
JAN 1994	1	7.000	6.000	8.000	7.000	7.667	6.667
FEB	7	7.000	0.000	1.000	6.000	4.000	3.000
MAR	9	7.000	2.000	7.000	2.000	5.333	3.667
APR	7	7.000	0.000	9.000	2.000	5.667	1.333
MAY	7	7.000	0.000	7.000	0.000	7.667	0.667
JUN	7	7.000	0.000	7.000	0.000	7.667	0.667
		MAD=	1.9091		3.6364		2.7000

MONTH	DEMAND	ALPHA = 0.25 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	7	7.000	0.350	7.350	
1993	5	7.263	0.346	7.608	2.608
SEPT	8	6.956	0.313	7.269	0.731
OCT	12	7.452	0.322	7.774	4.226
NOV	3	8.830	0.375	9.205	6.205
DEC	8	7.654	0.297	7.952	0.048
JAN 1994	1	7.964	0.298	8.262	7.262
FEB	7	6.446	0.207	6.654	0.346
MAR	9	6.740	0.212	6.952	2.048
APR	7	7.464	0.237	7.701	0.701
MAY	7	7.526	0.228	7.754	0.754
JUN	7	7.566	0.219	7.785	0.785
				MAD=	2.3377

NSN 7R 5841-01-120-4885
FINAL FORECASTS

MONTH	DEMAND	CAUSAL FORECAST	NON-CARR. TIME SERIES	RESID. TIME SERIES	NON-CARRIER MARGINAL	CARRIER RESIDUAL MARGINAL	TOTAL CAUSAL & TIME SERIES	ABS DEV	TOTAL CAUSAL & MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
AUG 1993	2	1.964	0.000	4.036	1.000	1.000	6	4.000	4	1.964	3	1.455
SEP	4	2.103	0.000	-0.104	1.000	1.000	2	2.001	4	0.103	3	0.545
OCT	1	1.746	0.000	-0.746	1.000	1.000	1	0.000	4	2.746	3	2.455
NOV	4	0.000	0.000	0.062	1.000	1.000	0	3.938	2	2.000	3	0.545
DEC	3	2.500	0.000	1.449	1.000	1.000	4	0.051	5	0.500	3	0.545
JAN 1994	0	2.799	0.000	0.384	1.000	1.000	3	0.183	5	1.799	3	0.455
FEB	1	1.187	0.000	2.087	1.000	1.000	3	3.274	3	3.187	3	3.455
MAR	9	2.561	0.000	1.733	1.000	1.000	4	3.294	5	3.561	3	2.455
APR	3	4.819	0.000	4.030	1.000	1.000	9	0.151	7	2.181	3	5.545
MAY	5	5.006	0.000	4.150	1.000	1.000	9	6.156	7	4.006	3	0.455
JUN	6	4.140	0.000	0.655	1.000	1.000	5	0.205	6	1.140	3	1.545
							MAD =	2.1139		2.1080		1.7686

NSN 7R 5841-01-120-4885 MARGINAL METHOD		p(M>Q) = 2290/10000 = 0.229			
BEST FORECAST	CARRIER RESIDUAL	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	-4	1	0.0909	0.0909	0.9091
	-2	1	0.0909	0.1818	0.8182
	-1	2	0.1818	0.3636	0.6364
	0	3	0.2727	0.6364	0.3636
→	1	2	0.1818	0.8182	0.1818
	3	1	0.0909	0.9091	0.0909
	4	1	0.0909	1.0000	0.0000
		11	1		
BEST FORECAST	NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	0	7	0.6364	0.6364	0.3636
→	1	2	0.1818	0.8182	0.1818
	2	1	0.0909	0.9091	0.0909
	3	1	0.0909	1.0000	0.0000
		11	1		

FORECASTS FOR 7R 5841-01-120-4885
CARRIER RESIDUALS

MONTH	RESIDUAL VALUES	ALPHA= 0.4 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
AUG 1993	4.036	4.036		3.278			
SEP	-0.104	4.036	4.140	3.278	3.381		
OCT	-0.746	2.380	3.126	-0.722	0.024		
NOV	1.000	1.130	0.130	-1.722	2.722	1.062	0.062
DEC	1.500	1.078	0.422	-1.722	3.222	0.050	1.449
JAN 1994	0.201	1.247	1.046	-1.444	1.645	0.585	0.384
FEB	-1.187	0.828	2.016	0.278	1.465	0.900	2.087
MAR	-1.562	0.022	1.584	-2.722	1.160	0.171	1.733
APR	3.181	-0.611	3.792	-1.722	4.903	-0.849	4.030
MAY	-4.006	0.905	4.912	2.555	6.561	0.144	4.150
JUN	-0.140	-1.059	0.919	-1.722	1.582	-0.796	0.655
		MAD=	2.2085		2.6666		1.8190

MONTH	RESIDUAL VALUES	ALPHA = 0.4 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
AUG 1993	4.036	4.036	0.202	4.238	
SEP	-0.104	4.157	0.198	4.355	4.458
OCT	-0.746	2.571	0.109	2.680	3.426
NOV	1.000	1.310	0.040	1.350	0.350
DEC	1.500	1.210	0.033	1.243	0.257
JAN 1994	0.201	1.346	0.038	1.384	1.183
FEB	-1.187	0.911	0.015	0.925	2.112
MAR	-1.562	0.080	-0.028	0.052	1.614
APR	3.181	-0.593	-0.060	-0.653	3.834
MAY	-4.006	0.880	0.017	0.897	4.903
JUN	-0.140	-1.064	-0.081	-1.146	1.005
				MAD=	2.3144

FORECASTS FOR 7R 5841-01-120-4885
NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
AUG 1993	0	0.000		0.000			
SEP	3	0.000	3.000	0.000	3.000		
OCT	0	0.000	0.000	0.000	0.000		
NOV	0	0.000	0.000	3.000	3.000	1.000	1.000
DEC	0	0.000	0.000	0.000	0.000	1.000	1.000
JAN 1994	0	0.000	0.000	0.000	0.000	0.000	0.000
FEB	0	0.000	0.000	0.000	0.000	0.000	0.000
MAR	1	0.000	1.000	0.000	1.000	0.000	1.000
APR	2	0.000	2.000	0.000	2.000	0.333	1.667
MAY	1	0.000	1.000	1.000	0.000	1.000	0.000
JUN	0	0.000	0.000	2.000	2.000	1.333	1.333
		MAD=	0.7000		1.1000		0.7500

MONTH	DEMAND	ALPHA = 0.05 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
AUG 1993	0	0.000	0.000	0.000	
SEP	3	0.000	0.000	0.000	3.000
OCT	0	0.150	0.008	0.158	0.158
NOV	0	0.150	0.007	0.157	0.157
DEC	0	0.149	0.007	0.156	0.156
JAN 1994	0	0.148	0.006	0.154	0.154
FEB	0	0.146	0.006	0.152	0.152
MAR	1	0.145	0.006	0.150	0.850
APR	2	0.193	0.008	0.200	1.800
MAY	1	0.290	0.012	0.303	0.697
JUN	0	0.338	0.014	0.351	0.351
				MAD=	0.7474

NSN 7R 6615-00-182-7733
FINAL FORECASTS

MONTH	DEMAND	CAUSAL FORECAST	NON-CARR TIME SERIES	RESID. TIME SERIES	NON-CARRIER MARGINAL	CARRIER RESIDUAL MARGINAL	TOTAL CAUSAL & TIME SERIES	ABS DEV	TOTAL CAUSAL & MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	5	3.893	0.000	1.107	1.000	-1.000	5	0.001	4	1.108	8	2.750
AUG	19	10.718	0.000	1.107	1.000	-1.000	12	7.176	11	8.283	8	11.250
SEP	12	13.624	0.000	1.107	1.000	-1.000	15	2.731	14	1.624	8	4.250
OCT	18	9.550	0.000	1.107	1.000	-1.000	11	7.343	10	8.450	8	10.250
NOV	5	3.062	0.000	1.107	1.000	-1.000	4	0.831	3	1.938	8	2.750
DEC	6	5.190	0.000	1.107	1.000	-1.000	6	1.297	5	0.190	8	2.750
JAN 1994	6	6.332	0.000	1.107	1.000	-1.000	7	1.439	6	0.332	8	1.750
FEB	0	5.398	0.000	1.107	1.000	-1.000	7	0.505	5	0.602	8	1.750
MAR	2	4.282	0.000	1.107	1.000	-1.000	5	5.389	4	4.282	8	7.750
APR	0	8.252	0.000	1.107	1.000	-1.000	9	7.359	8	6.252	8	5.750
MAY	8	10.017	0.000	1.107	1.000	-1.000	11	11.124	10	10.017	8	7.750
JUN	12	7.993	0.000	1.107	1.000	-1.000	9	1.100	8	0.007	8	0.250
							MAD =	3.8578		3.5904		4.9167

NSN 7R 6615-00-182-7733 p(M>Q) = 4240/10000 = .424
MARGINAL METHOD

BEST FORECAST	NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	0	6	0.5000	0.5000	0.5000
→	1	2	0.1667	0.6667	0.3333
	2	3	0.2500	0.9167	0.0833
	3	1	0.0833	1.0000	0.0000
		12	1		

BEST FORECAST	CARRIER RESIDUAL	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	-8	1	0.0833	0.0833	0.9167
	-5	1	0.0833	0.1667	0.8333
	-4	1	0.0833	0.2500	0.7500
	-2	3	0.2500	0.5000	0.5000
→	-1	1	0.0833	0.5833	0.4167
	1	2	0.1667	0.7500	0.2500
	4	1	0.0833	0.8333	0.1667
	6	1	0.0833	0.9167	0.0833
	7	1	0.0833	1.0000	0.0000
		12	1		

FORECASTS FOR 7R 6615-00-182-7733
CARRIER RESIDUALS

MONTH	RESIDUAL VALUE	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	1.107	1.107		1.107			
AUG	6.283	1.107	5.175	1.107	5.175		
SEPT	-1.624	1.107	2.731	6.283	7.906		
OCT	7.450	1.107	6.343	-1.624	9.074	1.922	5.53
NOV	0.938	1.107	0.170	7.450	6.512	4.036	3.10
DEC	-2.190	1.107	3.297	0.938	3.128	2.255	4.44
JAN 1994	-1.332	1.107	2.439	-2.190	0.858	2.066	3.40
FEB	-5.398	1.107	6.505	-1.332	4.066	-0.861	4.54
MAR	-4.282	1.107	5.389	-5.398	1.116	-2.973	1.31
APR	-8.252	1.107	9.360	-4.282	3.970	-3.670	4.58
MAY	-2.017	1.107	3.124	-8.252	6.235	-5.977	3.96
JUN	4.007	1.107	2.900	-2.017	6.024	-4.850	8.86
		MAD=	4.3121		4.9151		4.4127

MONTH	RESIDUAL VALUE	ALPHA = 0 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	1.107	1.107	0.055	1.163	
AUG	6.283	1.163	0.055	1.218	5.064
SEPT	-1.624	1.218	0.055	1.274	2.897
OCT	7.450	1.274	0.055	1.329	6.121
NOV	0.938	1.329	0.055	1.384	0.446
DEC	-2.190	1.384	0.055	1.440	3.630
JAN 1994	-1.332	1.440	0.055	1.495	2.827
FEB	-5.398	1.495	0.055	1.550	6.948
MAR	-4.282	1.550	0.055	1.606	5.888
APR	-8.252	1.606	0.055	1.661	9.913
MAY	-2.017	1.661	0.055	1.716	3.733
JUN	4.007	1.716	0.055	1.772	2.235
				MAD=	4.5185

FORECASTS FOR 7R 6615-00-182-7733
NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JUL 1993	0	0.000		0.000			
AUG	2	0.000	2.000	0.000	2.000		
SEPT	0	0.000	0.000	2.000	2.000		
OCT	1	0.000	1.000	0.000	1.000	0.667	0.333
NOV	2	0.000	2.000	1.000	1.000	1.000	1.000
DEC	3	0.000	3.000	2.000	1.000	1.000	2.000
JAN 1994	1	0.000	1.000	3.000	2.000	2.000	1.000
FEB	0	0.000	0.000	1.000	1.000	2.000	2.000
MAR	2	0.000	2.000	0.000	2.000	1.333	0.667
APR	0	0.000	0.000	2.000	2.000	1.000	1.000
MAY	0	0.000	0.000	0.000	0.000	0.667	0.667
JUN	0	0.000	0.000	0.000	0.000	0.000	0.000
		MAD=	1.0000		1.2727		0.9630

MONTH	DEMAND	ALPHA = 0.05 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JUL 1993	0	0.000	0.000	0.000	
AUG	2	0.000	0.000	0.000	2.000
SEPT	0	0.100	0.005	0.105	0.105
OCT	1	0.100	0.005	0.104	0.896
NOV	2	0.149	0.007	0.156	1.844
DEC	3	0.248	0.012	0.260	2.740
JAN 1994	1	0.397	0.018	0.415	0.585
FEB	0	0.445	0.020	0.465	0.465
MAR	2	0.441	0.019	0.460	1.540
APR	0	0.537	0.023	0.560	0.560
MAY	0	0.532	0.021	0.553	0.553
JUN	0	0.525	0.020	0.545	0.545
				MAD=	1.0755

NSN 7R 5826-00-117-4629
FINAL FORECASTS

MONTH	DEMAND	NON-CARR. TIME SERIES	ABS DEV	NON-CARRIER MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	10	10.000	0.000	9.000	1.000	7	2.917
AUG	6	6.000	0.000	9.000	3.000	7	1.083
SEP	7	7.000	0.000	9.000	2.000	7	0.083
OCT	8	7.667	0.333	9.000	1.000	7	0.917
NOV	6	7.000	1.000	9.000	3.000	7	1.083
DEC	6	7.000	1.000	9.000	3.000	7	1.083
JAN 1994	10	6.667	3.333	9.000	1.000	7	1.083
FEB	7	7.333	0.333	9.000	2.000	7	2.917
MAR	1	7.667	6.667	9.000	8.000	7	0.083
APR	9	6.000	3.000	9.000	0.000	7	6.083
MAY	8	5.667	2.333	9.000	1.000	7	1.917
JUN	7	6.000	1.000	9.000	2.000	7	0.917
		MAD =	1.5833		2.2500		1.6806

NSN 7R 5826-00-117-4629 MARGINAL METHOD			p(M>Q) = 2050/10000 = 0.205		
BEST FORECAST	NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	1	1	0.0833	0.0833	0.9167
	6	3	0.2500	0.3333	0.6667
	7	3	0.2500	0.5833	0.4167
	8	2	0.1667	0.7500	0.2500
→	9	1	0.0833	0.8333	0.1667
	10	2	0.1667	1.0000	0.0000
		12	1		

FORECASTS FOR 7R 5826-00-117-4629
NON-CARRIER DEMAND

		ALPHA= 0.35		LAST PRD		3 MONTH	
MONTH	DEMAND	EWMA FORECAST	ABS DEV	(NAIVE) FORECAST	ABS DEV	MOVING AVERAGE FORECAST	ABS DEV
JULY 1993	10	10.000		10.000			
AUG	6	10.000	4.000	10.000	4.000		
SEPT	7	8.600	1.600	6.000	1.000		
OCT	8	8.040	0.040	7.000	1.000	7.667	0.333
NOV	6	8.026	2.026	8.000	2.000	7.000	1.000
DEC	6	7.317	1.317	6.000	0.000	7.000	1.000
JAN 1994	10	6.856	3.144	6.000	4.000	6.667	3.333
FEB	7	7.956	0.956	10.000	3.000	7.333	0.333
MAR	1	7.622	6.622	7.000	6.000	7.667	6.667
APR	9	5.304	3.696	1.000	8.000	6.000	3.000
MAY	8	6.598	1.402	9.000	1.000	5.667	2.333
JUNE	7	7.088	0.088	8.000	1.000	6.000	1.000
		MAD=	2.2629		2.8182		2.1111

		ALPHA = 0.55		BETA = 0.05	
MONTH	DEMAND	LEVEL	TREND	FORECAST	ABS DEV
JULY 1993	10	10.000	0.500	10.500	
AUG	6	10.225	0.486	10.711	4.711
SEPT	7	8.120	0.357	8.477	1.477
OCT	8	7.665	0.316	7.981	0.019
NOV	6	7.991	0.317	8.308	2.308
DEC	6	7.039	0.253	7.292	1.292
JAN 1994	10	6.581	0.218	6.799	3.201
FEB	7	8.559	0.306	8.865	1.865
MAR	1	7.839	0.254	8.094	7.094
APR	9	4.192	0.059	4.251	4.749
MAY	8	6.863	0.190	7.053	0.947
JUNE	7	7.574	0.216	7.790	0.790
				MAD=	2.5866

NSN 7R 5895-01-162-9449
FINAL FORECASTS

MONTH	DEMAND	CARRIER & NON-CARR. TIME SERIES	ABS DEV	CARRIER & NON-CARRIER MARGINAL	ABS DEV	YOKOSUKA MODEL	ABS DEV
JUL 1993	8	8.000	0.000	11.000	3.000	9	0.667
AUG	8	8.000	2.000	11.000	1.000	9	1.333
SEP	10	8.000	2.000	11.000	1.000	9	1.333
OCT	10	8.000	3.000	11.000	6.000	9	3.667
NOV	5	8.000	1.000	11.000	2.000	9	0.333
DEC	9	8.000	4.000	11.000	7.000	9	4.667
JAN 1994	4	8.000	3.000	11.000	0.000	9	2.333
FEB	11	8.000	0.000	11.000	3.000	9	0.667
MAR	8	8.000	0.000	11.000	3.000	9	0.667
APR	8	8.000	4.000	11.000	7.000	9	4.667
MAY	4	8.000	11.000	11.000	8.000	9	10.333
JUN	19	8.000	8.000	11.000	11.000	9	8.667
		MAD =	3.1667		4.3333		3.2778

NSN 7R 5895-01-162-9449
MARGINAL METHOD

$p(M>Q) = 1180/10000 = 0.118$

BEST FORECAST	CARRIER AND NON-CARRIER DEMAND	FREQUENCY	PROBABILITY	C.D.F	1-C.D.F
	4	2	0.1667	0.1667	0.8333
	5	1	0.0833	0.2500	0.7500
	8	4	0.3333	0.5833	0.4167
	9	1	0.0833	0.6667	0.3333
	10	2	0.1667	0.8333	0.1667
→	11	1	0.0833	0.9167	0.0833
	19	1	0.0833	1.0000	0.0000
		12	1		

FORECASTS FOR 7R 5895-01-162-9449
CARRIER AND NON-CARRIER DEMAND

MONTH	DEMAND	ALPHA= 0 EWMA FORECAST	ABS DEV	LAST PRD (NAIVE) FORECAST	ABS DEV	3 MONTH MOVING AVERAGE FORECAST	ABS DEV
JULY 1993	8	8.000		8.000			
AUG	8	8.000	0.000	8.000	0.000		
SEPT	10	8.000	2.000	8.000	2.000		
OCT	10	8.000	2.000	10.000	0.000	8.667	1.333
NOV	5	8.000	3.000	10.000	5.000	9.333	4.333
DEC	9	8.000	1.000	5.000	4.000	8.333	0.667
JAN 1994	4	8.000	4.000	9.000	5.000	8.000	4.000
FEB	11	8.000	3.000	4.000	7.000	6.000	5.000
MAR	8	8.000	0.000	11.000	3.000	8.000	0.000
APR	8	8.000	0.000	8.000	0.000	7.667	0.333
MAY	4	8.000	4.000	8.000	4.000	9.000	5.000
JUNE	19	8.000	11.000	4.000	15.000	6.667	12.333
		MAD=	2.7273		4.0909		3.6667

MONTH	DEMAND	ALPHA = 0 LEVEL	TREND	BETA = 0.05 FORECAST	ABS DEV
JULY 1993	8	8.000	0.400	8.400	0.400
AUG	8	8.400	0.400	8.800	0.800
SEPT	10	8.800	0.400	9.200	0.800
OCT	10	9.200	0.400	9.600	0.400
NOV	5	9.600	0.400	10.000	5.000
DEC	9	10.000	0.400	10.400	1.400
JAN 1994	4	10.400	0.400	10.800	6.800
FEB	11	10.800	0.400	11.200	0.200
MAR	8	11.200	0.400	11.600	3.600
APR	8	11.600	0.400	12.000	4.000
MAY	4	12.000	0.400	12.400	8.400
JUNE	19	12.400	0.400	12.800	6.200
				MAD=	3.4545

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