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A COST MODEL OF ITEM MIGRATION IN THE AIR FORCE LOGISTICS COMMAND CONSUMABLE ITEM INVENTORY

THESIS

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Captain, USAF

AFIT/GOR/OS/86D-7

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A COST MODEL OF ITEM MIGRATION IN THE AIR FORCE LOGISTICS COMMAND CONSUMABLE ITEM INVENTORY

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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In Partial Fulfillment of the
Requirements for the Degree of
Master of Science

Lee J. Lehmkuhl, B.S.
Captain, USAF

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Preface

Air Force Logistics Command manages a large inventory of consumable items, totaling nearly 600,000 items. The management policy for this inventory assumes that items remain in specific management categories indefinitely. Numerous studies have shown that the opposite is true -- items tend to change categories, or migrate, over time. This item migration diminishes the effect of management policies tailored to specific categories. Attention has now turned to the implications of item migration, in terms of excess cost or decreased inventory performance.

A cost model for item migration was developed to determine the cost of item migration. The model was derived from a simplified inventory simulation model. Data on which the model was based were drawn from a previous study of item migration at San Antonio Air Logistics Center. Multiple runs of the model under different inventory conditions show that the speed with which inventory managers recognize item migration greatly affects the number of backorders resulting from upward migration. Even with instant recognition of item migration, however, the dollar value of backorders caused by item migration within the model averages about 4.7 million dollars per quarter. The value of long supply resulting from downward migration is influenced by varying lead time and the amount of safety level. But neither influence is strong enough to greatly affect the total value of long supply, which averaged about 75 million dollars.

This study would not have been possible without the help of several dedicated people. Mark Fryman, Patti Moore, and Fred Rexroad provided much-needed insight into the AFLC data base and item management policy. Special thanks go to my advisor, Maj Joseph R. Litko, for his suggestions, ideas, and support; and Lt Col Palmer W. Smith, USAF (Ret), for giving me a solid foundation in this area and staying with the project. Finally, I thank my wife Michele for her unfailing support and caring during my tour at AFIT.

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Abstract

This ~~research effort~~ investigates the phenomenon of item migration within the Air Force Logistics Command (AFLC) consumable item inventory. Item migration is the movement of items between the Supply Management Grouping Codes (SMGC) used by AFLC to categorize items. Since SMGCs are based on dollar value of annual demand, item migration entails substantial changes in demand rate. Migration to a higher level of demand gives rise to backorders, while downward migration may result in unneeded stock on hand, or "long supply."

A simplified model of the AFLC item management system provides the means for experimentation within the inventory system. By using a constant quarterly demand rate with discrete changes in the demand rate as migration occurs, the model is able to isolate the backorders and long supply resulting strictly from migration. The influences of the speed of recognition of migration, the variability of lead time, and the amount of safety level are determined by running the simulation under various conditions. An analysis of variance for the dollar value of both backorders and long supply provides insight into the negative effect of item migration on inventory performance.

Migration creates high levels of both backorders and long supply within the simulation. The amount of backorders

is influenced only by the reaction time of the inventory management system to rising demand. Varying read time and different safety levels have little effect on backorders stemming from upward migration. Long supply is affected by both varying lead time and safety levels, but not by management reaction time. However, the effects of lead time and safety level, while statistically significant, are quite small when compared with the overall amount of long supply.

A COST MODEL OF ITEM MIGRATION IN THE AIR FORCE LOGISTICS COMMAND CONSUMABLE ITEM INVENTORY

I. Introduction

Background

The Air Force Logistics Command (AFLC) is responsible for maintaining the Air Force inventory of consumable items, that is, items not repaired after they wear out. Item managers, with the aid of the DO-62 computerized inventory control system, track the stock level of each item and request purchase of replacement stock when needed. Stock is purchased in quantities which minimize the overall cost of maintaining the inventory, based on a model of the inventory system.

To avoid the time-consuming process of closely monitoring each of the nearly 600,000 items in the consumables inventory, AFLC divides the inventory into three management categories. The projected dollar value of yearly demand for an item determines the item's category. Items in the high value category receive close scrutiny from the item manager to avoid excessive backorders or costly unnecessary purchases. Items in the middle category receive a moderate degree of item manager attention. For low value items, item managers depend a great deal on the DO-62 system to automatically calculate stock levels and determine when to buy more stock. Under this system, an evaluation of management practices can reveal management-related problems within a specific category. AFLC then develops new policies targeted for that category.

Item management under this system becomes more difficult, however, when an item's dollar value of demand changes significantly. This causes the item to move, or migrate, to another category. Item migration makes the evaluation of management policies within a category less straightforward. A problem with an item (for example, too much stock on hand) may have started when the item was in a category other than the current one, under different management policies. In this case, a management change in the current category has no effect on the actual cause of the problem. Since purchase amounts are related to demand, item migration also leads to incorrect purchasing. A purchase initiated when an item is in one category may arrive after the item has migrated and be too large or too small given the new level of demand.

Lt Col Palmer W. Smith and Mr. Robert Gumbert first identified item migration and its effect on stock levels and purchases at the Defense Electronics Supply Center (DESC). Their study covered the entire DESC inventory from 1976 to

1980. A subsequent AFIT Masters thesis by Capt Kevin Smith attempted to incorporate item migration into the DESC inventory simulation model. More recently, an AFIT Masters thesis by Capt J. D. Kennedy has quantified item migration within the AFLC consumables inventory. A detailed discussion of literature pertaining to item migration is presented in Chapter II.

Problem Statement

Item migration complicates the task of managing the AFLC consumables inventory. It makes evaluation of management policies within management categories difficult. Backorders result when low-demand items migrate upward. and excess stock accrues in the low value category as high-demand items migrate downward. Item migration has not been successfully modeled, preventing any estimate of the cost of item migration or analysis of new policies addressing item migration.

Research Question

How can item migration be modeled within the context of existing inventory models and management practices? This question gives rise to several subsidiary questions. How do item management practices differ between management categories? How time-dependent is the probability of an item migrating? How best can item migration be effectively modeled? What is the dollar value of item migration in terms of backorders and excess stock? What effect does information on changing demand have on the cost of item migration?

Research Objective

It is the purpose of this investigation to develop a simulation model of item migration within the AFLC consumables inventory and, based on the model, estimate the cost of item migration. This overall objective requires the fulfillment of the following subsidiary objectives:

1. Determine the amount of migration in the consumables inventory.
2. Create a simple model of the inventory, simulating the occurrence of item migration.
3. Validate modeled item migration.
4. Estimate the cost of item migration.

Scope

This research is limited to item migration only within the AFLC consumable item inventory at the San Antonio Air Logistics Center. Migration patterns are derived from item migration data presented in the Kennedy thesis (Kennedy). The simulation of the AFLC inventory is based on a simplistic model of the AFLC consumables inventory developed by Disz (9:24-25). This model is modified to include item migration. The study does not use the large AFLC inventory simulation model, EOQSIM.

Overview

Chapter II is a review of literature pertinent to item migration. The review covers professional journals, technical reports, and past theses.

Chapter III presents a detailed background for the research conducted. There is a thorough description of the DO-62 inventory control system, including the computations performed within the system. The data from the Kennedy thesis (Kennedy), which forms the basis for model development, is covered; and lastly, Chapter III covers the general context in which the model will be used.

Chapter IV describes the methodology for developing the simulation model and presents a description of the model. Chapter IV also covers the validation of the model and concludes with a discussion of the design of the experiment to be performed with the model.

Chapter V presents the results of the research and analysis of those results.

Chapter VI contains the conclusions and implications drawn from the analysis in Chapter V, and concludes with recommendations for additional research.

II. Literature Review

Introduction

The literature review includes professional journals and periodicals; technical reports produced by the Air Force, contractors, universities, and others; and past theses by students at the Air Force Institute of Technology. The review covers three main areas. First, it presents documents or studies pretaining to the AFLC consumables inventory. Second, it discusses studies of the underlying dynamic nature of an inventory system which gives rise to item migration. This includes random changes in demand and lead time (the time to receive an order of replenishment stock once the order is placed) and techniques for quantifying and dealing with these random changes. Third, the review covers attempts to specifically analyze item migration within inventory systems, the approaches taken, and results achieved.

Discussion of the Literature

AFLC Consumables Inventory. The management of the AFLC consumables inventory is governed by AFLC Regulation 57-6 (AFLCR 57-6). AFLCR 57-6 describes in detail the functioning of the D0-62 computer system which automates the management process and all management policies affecting the inventory. Of special interest is the criterion for an item to change management groups. An item must exhibit an annual demand rate well in excess of current category specifications for three consecutive months to enter another category (1:12). The specific criteria for entering each SMGC are discussed in Chapter III, Section 1. A recent study of the consumables inventory found significant demand and lead time fluctuations. This information was compared to the way demand and lead time are modeled within AFLC's consumables inventory simulation, EOQSIM. EOQSIM is a large, complex discrete event simulation of the DO-62 system. It couples the demand forecasting techniques of DO-62 with stochastically determined requisitions based on actual experienced demand and an empirical distribution of requisition size (7: Sec III, 6). EOQSIM is run on a stratified sample of the consumables inventory. Several key assumptions within EOQSIM concerning the stationarity of inventory parameters may be incorrect, including the methods for forecasting demand and lead time (8:49).

Another study of the consumables inventory, concerned with the impact of increasing the minimum order size, developed a simplified model of the inventory system (9:24-25). This model, created by Mr. Thomas E. Disz, aids in the analysis of management policy changes without resorting to the complex and possibly flawed EOQSIM model. The Disz approach avoids the complications of stochastic demand, lead time demand, and population sampling present in EOQSIM. (9:25; 8:49-50). The Disz model employs a constant level of demand over a ten year period. This drives a steady series of stock purchases to replenish the inventory. Because of its simplicity, the Disz model may be run using the entire AFLC inventory. This eliminates the need for a stratified sample of the inventory, a potential source of error. The model was run several times with different minimum buy policies. (A minimum buy is the smallest amount of stock that can be purchased at one time, given in months of demand.) The results provided an estimate of the cost of different minimum buy policies (9:25,38).

Inventory Dynamics. Inventory dynamics is a term covering the changing nature of items within an inventory. It includes the varying nature of demand, lead time, and methods to analyze and compensate for this variation.

Varying Demand. Much of the movement within an inventory is caused by varying levels of demand. Recent improvements in technology have contributed to the variation. The complex technology associated with new systems requires more complex, expensive replacement parts, while improvements in the quality and reliability of such parts have decreased the quantity demanded. Additionally, many of these expensive components are modular in nature. Modular components allow rapid replacement of failed parts, demanding a faster response from the inventory system for the replacement part (5:17-18). This situation results in a significant number of high-cost, high-priority parts with sporadic demand (5:18).

Demand within the AFLC consumables inventory is highly erratic. Current policies are based on the assumption that actual demand is normally distributed with a mean value equal to the forecasted demand rate. But based on empirical data over several years, the actual distribution of demand appears highly skewed with a large number of sample demand levels in excess of the forecasted demand rate (6:9). A varying demand rate is a standard feature of real-world inventory systems, and much effort has been devoted to expressing the variation in theoretical statistical distributions. Such distributions allow the derivation of explicit management policies to minimize the cost of incorrectly predicting demand. The payoff for such research can be great. The Air Force consumables inventory accounts for 64 percent of all base-level supply transactions and seven billion dollars of yearly Air Force requirements (3:11). Recent changes in computing the variability of demand at base level are expected to increase the number of successfully filled requisitions throughout the Air Force by 14 percent (3:22). One theoretical treatment of demand variability used a combination of the Poisson distribution and the geometric distribution to express erratic demand. The Poisson was used to predict the arrival of customer requisitions, and the geometric to model the size of the individual requisitions. The use of this distribution, known as the stuttering Poisson, led to an empirical formula for calculating the reorder point to minimize inventory cost (19:624). (The reorder point is the level of stock on hand which, when reached, indicates that more stock should be purchased.)

Varying Lead Time. Lead time variation is a major problem for inventory managers. When an order takes longer to arrive than expected, backorders result, and support to inventory customers suffers. Lead time greatly affects inventory costs. In fact, the total effect is greater than that of demand variations over a given time period (2:158). Approaches to handling lead time vary. Management policy may treat lead time as a constant or, as in the case of the Air Force, use the lead time resulting from the last order for the item in question. Additional approaches are using the longest lead time previously occurring (to be on the safe side) or developing a distribution of possible lead time values using historical data (2:159-160). This last approach was used by Bagchi, Hayya, and Ord in developing a distribution for demand occuring during lead time, or lead time demand. They modeled lead time demand as a compound distribution based on three varying elements: lead time, number of requisitions, and the size of individual roquisitions (2:161).

Safety Level. Safety level is a quantity of stock held in the inventory. It provides a hedge against backorders resulting from greater-than-expected lead time demand. AFLC calculates safety levels using a formula developed by Presutti and Trepp. The formula was derived using the Method of Lagrange, minimizing inventory costs subject to a constraint on total backorders. The derivation assumes normally distributed lead time demand with a mean provided by averaging historical demand. The formula provides the optimum amount of safety level for a given item based on item demand, demand variability, cost, and the cost of a backorder (13:243,249). AFLC may then adjust the value used for the cost of a backorder to remain within the budget for safety level expenditures (13:250).

Parameter Estimation. Besides using a safety level, other techniques exist for compensating for variations in demand and inaccurate management policies. Key parameters used in computing when and how much stock to buy are holding cost, ordering cost, and demand rate. These parameters are often estimated, and inaccurate estimates may be costly. Lowe has developed a method for estimating these parameters by minimizing the deviation between the actual average cost incurred and the theoretical average cost given perfect information about the distribution of demand. The method works for both stationary parameters (unknown but fixed within a given range) and unstationary parameters (unknown and varying within a given range) (12:368-369).

Item Migration Studies. Several past studies have identified and quantified item migration in different inventory systems.

Identifying Item Migration. The first research into item migration was that of Smith and Gumbert at the Defense Electronic Supply Center (DESC). They documented and quantified high levels of migration between the five DESC item management categories from March 1976 to March 1980. Their findings revealed there is an error in evaluating the effectiveness of management category policies based only on the observation of items currently in the category: items may move into a category, and the status of such items will have nothing to do with the policies for that category (18:4-5). A study by Kennedy has found significant levels of migration in the AFLC consumables inventory (11: Sec IV, 1). The analysis tracked on an item-by-item basis three consecutive years of inventory data from San Antonio Air Logistics Center. Kennedy provides accurate percentages of items migrating between the three AFLC management categories from quarter to quarter (11: Sec III, 3).

Modeling Item Migration. In a follow-on effort to Smith and Gumbert, Hobson and Kirchoff investigated the use of a Markov chain to describe the movement of items between management categories at DESC. The transition probabilities proved to be time-dependent and unstable using the management categories defined by DESC (10:36,61). The use of different categories based on both demand value and time in current category reduced the instability, but the transition probabilities remained unstable (10:64-66). Further work at DESC attempted to model demand by fitting theoretical probability distributions to demand data on various groupings of items. The demand distributions could then model actual demand and item migration patterns for these groupings (16: Sec II, 5). However, "Simulation results were very dependent on the item characteristics used to define the groupings" (16: Sec V, 31). The item migration patterns from the model did not match observed item migration patterns (16: Sec VI, 3).

__Proposed Policy Changes Addressing Item Migration__. Although Markov chains failed to model DESC item migration, Hobson and Kirchoff used DESC migration patterns to develop a proposed policy for buying replenishment stock in medium and high value categories. A comparison of the time an item had been in a category and the percentage of time such an item would migrate to a lower category showed a linear relationship (10:69-71). The proposed policy used this relationship to decrease the size of replenishment order based on the time in category. For medium value items, this involved buying about 60 percent of a normal order for an item in the category for only one quarter. This percentage increased linearly with time until a full order was recommended for items with more than 12 quarters in a category. High value order size varied from three months worth of demand for items in the category for only one quarter, climbing to a 12 month maximum order size (specified by regulation) when the item exceeded 20 quarters in the category (10:71-72).

III. Background

AFLC Item Management

The Economic Order Quantity Requirements Computation System (DO-62). DO-62 is a computerized data management system designed to gather data, compute requirements, and provide the information necessary for intelligent management of the non-recoverable items in the AFLC inventory. The system has two computation processes. One computes and identifies procurement actions required for support of DOD missions. This is done on an exception basis, when items fall outside specific parameters within DO-62 (1:13). The other process projects funding requirements for the procurement of necessary stock. This research effort is concerned with the former, the item management function of DO-62.

The primary function of DO-62 for item management is the computation of stock levels and projected requirements. Requirements are forecasted based on past demands. "The system runs four times each month using the most current asset...and demand data..." (1:13). DO-62 items are managed "by exception". Computations and updates to stock levels and demands are performed automatically, and the item manager is notified only when the asset position for an item violates specified parameters (1:13). For example, when the stock level for an item falls below a certain level, the system generates a notice to purchase more stock.

DO-62 is structured so that management intensity for an item depends on the dollar value of demand for that item. High demand value items are given the closest scrutiny to ensure effective, cost-efficient management. To this end, items are categorized by their annual dollar value of demand into Supply Management Groupings, denoted by a Supply Management Grouping Code (SMGC) (1:12). The item data used in this study are from June 1981 to March 1984. At that time AFLC used four SMGCs. In December 1984 AFLC reduced the number of SMGCs to three, but since all data are based on four SMGCs, the pre-December 1984 SMGCs are used (11: Sec II, 3). The four groupings are:

<u>SMGC</u> <u>X</u>. These are the low value items, with a yearly demand value of $0 - $500. Items in this SMGC receive a low level of management intensity. Item data are reviewed occasionally for accuracy. If an item in this SMGC has an annual demand rate of $2600 or more for 3 consecutive months, the item is reassigned to another SMGC.

<u>SMGC</u> <u>I</u>. These are the medium value items, with a yearly demand value of $500.01 - $5,000. Items in this SMGC receive a moderate level of management intensity. Item data are reviewed regularly for accuracy, especially when the system indicates that more stock should be purchased. If an item in this SMGC has an annual demand rate of less than

400.01 or more than $5,100 for three consecutive months, the item is reassigned to another SMGC.

SMGC P. These are the high value items, with a yearly demand value of $5000.01 - $50,000. Items in this SMGC receive a high level of management intensity. Item data are reviewed often for accuracy, and is closely reviewed when the system indicates that more stock should be purchased. If an item in this SMGC has an annual demand rate of less than 4900.01 or more than $50,000 for three consecutive months, the item is reassigned to another SMGC.

SMGC M. These are the very high value items, with a yearly demand value of over $50,000. Items in this category receive a very high degree of management intensity. Item data are reviewed constantly, and all data involved in the computation of a purchase request are scrutinized to ensure no unnecessary stock is purchased. Large requisitions for stock are also double-checked to make sure the user has a legitimate need for a large quantity of such high-value assets. If the annual demand for such en item falls below 49,000.01 for 3 consecutive months, the item is reassigned to a lower category (1:12,22).

High Intensity. High intensity management may be specified for an item in any SMGC when that item has great impact on supply availability (fill rate) or when the ALC responsible believes that intensified management will significantly improve support. Items so specified receive the highest degree of management intensity. All input data are screened extremely carefully, and all management actions are subject to close scrutiny for accuracy, completeness, and timeliness (1:12-13,22-23).

Functions of DO-62. This section covers the main areas of item information calculated and/or maintained by DO-62. This information allows DO-62 to accurately track the status of items within the system, maintain a history of the demand for the item, and forecast future demand for the item. DO-62 maintains information on assets, past demand, and projected requirements; calculates various stock levels; and computes the economic order quantity for purchases of replenishment stock.

Assets. Assets are the stock available within the system to meet the demands of item users. Assets fall into several categories. Item manager controlled assets are stored in depot supply warehouses. The issue of these items is directed by the item manager. Depot supply assets are issued by the item manager to the depot to cover the required depot supply level. These assets are issued by the depot supply clerk. In-transit assets are stock being moved from one depot to another. Due-in assets are stock which has been purchased but has not yet been received, as well as stock arriving from reclamation or as support from other services (1:20,21). Unservicable assets are unservicable, repairable items which are expected to be repaired to serviceable condition. The number of unservicable items is multiplied by a condemnation factor to determine how many are expected to be returned to service (1:21). Since DO-62 items are considered non-recoverable, the condemnation factor is usually 1.0, leaving zero unservicable assets for use in the total asset computation.

Assets used in computation are the total of the above asset categories. This total is used in all calculations in DO-62 requiring total available assets for an item (1:20).

Demand history. As stated above, DO-62 uses past demand data to project requirements for support. The system maintains a past history of the current quarter and last two years (eight quarters) demand data for each item. Demand data include demand history by quarter, stock returned unused, the demand level used in DO-62 computations, and requisition frequency.

Demand history by quarter is the sum of the quantities on all requisitions received during the quarter unless the requisition was cancelled by the item manager. These are demands by end users only, not shipments to depot supply or other storage sites. Demand history includes total sales, one-time demands, and transfers to base-level supply. Total sales is stock issued by both the item manager and depot supply (1:13-14). Besides Air Force maintenance functions, end users include overhaul and repair contractors and other services and DOD agencies. One-time only demands are generated by activities such as initial activation of a system or a one-time exercise. These are recorded as non-recurring demands and are considered in projecting demand for low demand value items. Transfers to base-level supply are free issue, so reimbursement occurs when the sale is made at base supply (1:13).

Serviceable returns are stock that was returned to the depot in suitable condition for re-issue. Returns are identified to the original stock issue.

DO-62 computes a level of demand for use in DO-62 computations. Demands used in computation are calculated differently for different SMGCs. Within SMGC X and T, demands used in computation equal the total sales plus non-recurring demands plus transfer demands. Within SMGC P and M, demands used in computation equal the total sales plus transfer demands minus servicable returns (1:78).

Requisition frequency is a quarterly count of the number of requisitions received. Non-recurring requisitions are not counted (1:14).

Requirements. Requirements are projected demands for items. DO-62 tracks several areas of requirements data -- monthly demand rate, program demand rate, quantitative requirements, depot level maintenance requirements, and several requirements factors.

Monthly demand rate is the expected rate of monthly demand determined from the demand history discussed earlier.

It is computed by taking the average of the quarterly demand over the last eight quarters. This is a moving average, always based on the current quarter and the eight quarters just preceding. There is an option to use only the four previous quarters when the item manager believes this will give a more accurate projection of demand (1:13-14,78).

Quantitative requirements are known additional requirements for the next three years, over and above the projected demand indicated by item history. Quantitative requirements are added to the program demand rate for the quarter in which they will occur to project the total support required in that quarter (1:16).

Depot level maintenance requirements, as the name implies, are parts requirements for depot level maintenance. They are computed separately. The schedule for such maintenance is known with certainty, and therefore, so is the parts requirement. This requirement is also added to the program demand rate for total demand projections (1:16).

Requirements factors are used in projecting requirements. They are either supplied by AFLC inventory management or computed within the DO-62 system. The primary requirements factors are the peacetime program ratio (PPR) and lead time. The PPR is a factor used to adjust the monthly demand rate to reflect upcoming changes in the rate of use for the supported system. The program demand rate is the monthly demand rate multiplied by the PPR (1:78). For example, a known increase in flying hours for a particular aircraft will result in a PPR greater than one for some components of that aircraft, to reflect the increased consumption of parts. For items with no usage fluctuations from increases in system operation, the PPR equals one.

Lead time is the number of days between the time DO-62 outputs a notice to buy stock and the time when ten percent of the normal deliveries of that order arrive. Lead time has two components, administrative lead time and production lead time. Administrative lead time is the amount of time that elapses from the output of the buy notice to the letting of a contract for the procurement of the required stock. It consists of both the time it takes for the Directorate of Material Management (MM) to prepare a purchase request, and for the Directorate of Contracting and Manufacturing (PM) to process the purchase request and award the contract or purchase order. The MM time is a maximum of 30 days for SMGC X items, 21 days for T and P items, 16 days for M items, and 14 days for high intensiity management items (1:14). The PM time is projected from the previous procurement action for that item. If the previous procurement is not representative of a normal buy, the item manager may substitute a more realistic PM time (1:15).

Production lead time is the amount of time it takes the contractor to produce the required stock, beginning with the letting of the contract. The time of stock arrival is the time when ten percent of the total normal deliveries of the purchase have arrived. Normal deliveries do not include special "rush orders" arriving ahead of the bulk of the purchase. Production lead time is projected by using the time required during the previous purchase for the item. If that purchase was not representative of a normal purchase of that item, the item manager may substitute a more realistic production lead time (1:15).

Computed Levels. Computed levels are the internal control parameters on DO-62 assets. When asset position violates a level, a notice of the occurrence is printed for the item manager. The two most important levels are the reorder level and the safety level. The amount of stock due out, lead time demand, and the amount of funded war reserve materiel all influence the level computations.

The reorder level (ROL) is that level of stock on hand which, when reached, indicates that more stock should be ordered. It is equal to lead time demand plus due-outs plus safety level plus depot supply level plus funded war reserve materiel. Each of these components is discussed below (1:19).

Lead time demand is the projected demand for the item during lead time. It is the sum of the following two demand projections: (1) the program demand rate computed from historical data multiplied by the lead time and (2) the quantitative requirements projected during lead time (1:79).

Due-outs are stock already committed to issue. Due-outs are added to the ROL since they cannot be used to meet demands during lead time (1:16). Depot supply level is the amount of supply required at depot level for each of the five ALCs. Funded war reserve materiel is all funded requirements for war reserve materiel on hand, on order, or to be bought (1:19).

Safety level is a variable quantity required to help support peak periods of demand and minimize shortages. The safety level factor K is the number of standard deviations worth of lead time demand (denoted as O) to allow as a safety level on a particular item. The computation of K and O are explained in the following paragraphs.

First compute the mean absolute deviation of demand (MAD). MAD is the average over the item history of the difference between each quarter's actual net recurring demands and the quarter average projected by historical data. The formula for the absolute deviation (AD) for each quarter is:

$$AD = |\text{Demands} - (3 * \text{monthly demand rate})|$$

The formula for MAD is:

$$MAD = \frac{\text{sum of ADs for all quarters in computation}}{\text{number of quarters in computation}}$$

MAD is converted to the standard deviation of lead time demand (θ) by the equation:

$$\theta = PPR * .5945*MAD * (.82375 + .42625*leadtime)*.85$$

where .82375 and .42625 express MAD over lead time and recognize that a particular month's demands are influenced by previous months' demands, and .5945 converts the quarterly MAD to a monthly MAD (1:80).

With these computations complete, the formula for K is:

$$K = -.707*\ln\left[\frac{\sqrt{2}\,Qac}{.5\,\lambda Z\theta(1-\exp(-\sqrt{2}\,Q/\theta))}\right]$$

where

- a = holding cost factor
- c = unit cost
- Q = economic order quantity (discussed later)
- λ = implied shortage factor
- Z = 1/ square root of average requisition size
- θ = standard deviation of lead time demand.

The value of K must be greater than or equal to zero; so, if this equation returns a negative value, K is set equal to zero. The safety level equals K*θ. The average requisition size is obtained by dividing the actual demand for the item over the item history by the number of requisitions (1:80). The economic order quantity is discussed in the next paragraph.

Purchase of stock. DO-62 initiates a notice for the item manager to prepare a purchase request when the assets on hand fall below the reorder level. DO-62 also computes the Economic Order Quantity (EOQ) (1:19,22). This computation is based on the standard Wilson's Lot Size equation to minimize total cost. The equation is:

$$EOQ = \sqrt{\frac{2AC}{H}}$$

where

EOQ = dollar value of stock to be purchased
A = dollar value of annual demand using actual unit cost
C = cost to order
H = cost to hold

This value is constrained to avoid very large or small quantities. For the time period with which this study is concerned, the EOQ can be no less than 6 months of demand and no more than 3 years (1:80-81). This computation may be overridden when a larger buy is absolutely necessary, such as when the sole source of a part ends production and lifetime requirements of that part must be purchased. Quantity discounts and limited shelf life may also require deviations from standard EOQ computations (1:25).

Research Data Base

This research effort uses two main sources of data. Item migration data comes from the Kennedy thesis (Kennedy). Data on SA ALC inventory items was transfered from the DO-62 master tape for the March 1984 quarter.

Item Migration Data. The Kennedy thesis provides the data upon which the item migration model will be based. The most useful data resulting from Kennedy's work are the tables of numbers of items migrating or remaining in each SMGC. Figure 1 is an example of a migration table for one quarter. The tables from the San Antonio ALC consumables inventory provide the only consecutive twelve quarters of data (May 1981 to March 1984), and are therefore used in this study.

FROM/TO	X	T	P	M	OUT
X	131096	1133	123	7	6652
T	772	20708	392	2	683
P	35	362	7611	87	296
M	6	1	43	1294	60
IN	2686	35	38	8	0

Fig. 1. Migration Table (11: Appendix C, 6)

Study of the migration tables revealed some significant anomalies in the data. In both the fifth and eleventh quarters, large numbers of items left the inventory. The fifth quarter exodus was the result of a policy change, causing items to be transfered to other non-Air Force inventories. No specific reason was found for the eleventh quarter item transfers, but given the amount of items leaving it would appear that another policy change may have occurred. Because these two quarters were not representative of normal inventory operation, they were dropped from the research data base.

The remaining migration tables provided the foundation for the transition matrix for the migration model. The migration counts were converted to percentages by dividing each row entry by the sum of the entries in the row. Each migration percentage was averaged over all quarters. This resulted in the transition matrix shown in Figure 2.

FROM/TO	X	T	P	M	OUT
X	.944888	.012922	.001377	.000157	.040656
T	.042693	.899571	.032440	.000250	.025046
P	.007964	.043185	.907705	.017894	.023252
M	.004731	.001040	.041668	.926699	.025862
IN	.903474	.063613	.026530	.006383	0.0

Fig. 2. Migration Transition Matrix

Kennedy also provided data on the relationship of migration to the amount of time an item has been in a SMGC. All items in each SMGC at the start of the twelve quarters of data were tracked until they left the SMGC. This showed the draw-down of items within the SMGC over time. Items at DESC had been found to be less likely to migrate the longer they remained in a category (18:10); Kennedy sought to find out if the same was true at AFLC. If it was, one would see a decreasing percentage of items leaving the initial group in the SMGC from quarter to quarter. Analysis of the draw-down of the initial stock of items in each SMGC does not support this premise. The fraction of items leaving each quarter shows no detectable pattern over the twelve quarter period for any of the SMGCs. For this reason no attempt was made to incorporate any time-related migration data in the model.

Inventory Data. Item data was gleaned from the DO-62 master tape. The tape was read onto the AFIT VAX 11/780 CSC computer system as an ASCII text file. A FORTRAN program extracted the following fields:

1. Price: the actual unit price.
2. Total assets: the sum of assets used in computation, as discussed in Section III-1.
3. Peacetime program ratio.
4. Program monthly demand rate.
5. Lead time.
6. Mean absolute deviation.
7. Average requisition size.

The AFLC data presented the same problem encountered by Disz: some numerical fields carried the sign as an overstrike on the last character in the field (9:36). A modification of Disz's FORTRAN subroutine to translate the overstrikes, incorporated in the program to extract the data, alleviated this problem (9:74-75).

The data described above formed records for each of the nearly 140,000 items in the SA ALC inventory. This master file was then sorted into separate files for each SMGC. Additionally, SMGC X was divided into two files: one for items with zero demand and one for items with non-zero demand. This sorting provides for later statistical analysis of item data within each SMGC and for zero demand items.

Model Context

Any model of item migration within the AFLC consumables inventory should start with a model of the inventory itself, including the management procedures and policies used by AFLC. In this way item migration may be modeled within the context of AFLC inventory management, and the influence of that management on item migration may be explored. Without a solid model of the AFLC inventory as a foundation, a migration model can provide no meaningful insights into AFLC item migration.

Item migration is nothing more than a change in the dollar value of demand for an item that is large enough to propel that item into a different SMGC. The limits of the SMGC are a threshold over which demand changes must rise to cause the item to migrate. A model of item migration should show the effect of demand changes above this threshold. The effects of migration are most visible in terms of backorders and excess stock on hand, so the model should provide these performance indicators.

Information on demand changes also may contribute to the effects of migration. The model should allow for evaluating the effect of the speed with which the inventory management system recognizes the new level of demand for a migrating item. The DO-62 system currently has a one quarter lag between demand change and item migration. The effect of instantly recognizing the demand change and moving the item to the new SMGC may be considerable.

There are other factors which may contribute to or mitigate the effects of migration. Lead time often increases as the dollar value of demand increase, since larger orders take longer to process and fill. Lead time changes also contribute to backorders. The model should provide for a comparison of migration effects with lead time held constant and with changing lead time. Another factor influencing backorders is the implied shortage factor. The implied shortage factor is determined from the amount of funds available for safety level stock. The less safety level funding available, the smaller the implied shortage factor, and the lower the safety level. Lower safety levels allow a greater potential for backorders. The model should allow for different values of the implied shortage factor to determine the effect of safety level on migration-induced backorders.

IV. Methodology

Model Development

This research effort centers around the use of the Disz inventory simulation model described in Chapter II. To effectively model item migration, the Disz model requires extensive modification. Many assumptions and simplications concerning the D0-62 system are also necessary to keep model complexity within manageable limits. First, key assumptions and simplifications are incorporated in the model. Then, specific modifications to the Disz model allow the it to model migration within the context of the AFLC consumables inventory.

Assumptions and Simplifications. The D0-62 system, discussed in Section II, is a very complex inventory management system. Without significant simplifications, a model of D0-62 would be so large and cumbersome that validation and analysis of results would be difficult if not impossible. Assumptions about the nature of items within the inventory are also necessary. Within the simulation model, items need to be created to enter the inventory. The parameters associated with these items should conform as much as possible to those of real items, and this requires assumptions for a "typical" item entering the inventory. The following paragraphs discuss the assumptions and simplifications underlying the item migration model.

The greatest simplification of the model is the use of a constant, or "straight line", demand for items in the inventory. The Disz model also used this simplification. Items will migrate between quarters, so the demand during any one quarter will be at a constant rate, with the possibility of an instant change to a different constant rate for the next quarter if migration occurs. If the item does not migrate, demand continues at the same constant rate. The substitution of constant demand for random demand allows the model to eliminate backorders caused by small demand fluctuations. The backorders generated will be the result of item migration only. Additionally, constant demand greatly reduces the complexity and required computational effort of the model.

Quarterly migration is modeled based on the assumption of a stationary Markov process. The cumulative transition matrix discussed in Chapter III provides the probability of migration for items in each SMGC. This is similar to the approach attempted by Hobson and Kirchoff; however, the same stationarity criteria is not applied. The model centers on approximating AFLC migration patterns to a reasonable level to allow valid experimentation within the model.

Another important assumption is that all items in an SMGC have an equal chance of migrating. This disregards the possibility of items near the boundary of the SMGC having a greater likelihood than other items of migrating the short distance to the adjacent category. Support for this assumption comes from the significant amount of large demand changes within the DO-62 system. According to an AFLC study, during a twelve quarter period, 38.8 percent of the items in the SA ALC consumables inventory experienced a demand fluctuation of from 50 percent to over 4900 percent. Item migration appears to involve considerable changes in demand (4:12). Additional support for this assumption comes from Dr. Palmer W. Smith. Quoting his work at DESC, Dr. Smith points out that over a nine quarter period at DESC, less than 0.10 percent of the items in the 1 million item DESC inventory moved back and forth between adjacent categories every quarter, and only 0.20 percent moved back and forth between adjacent categories every two quarters. The lack of back and forth movement also shows that item migration is not a transient change in demand. Items in general do not jump back and forth across a category boundary (17).

To further simplify the model, certain item parameters are held constant. These parameters are mean absolute deviation of demand (MAD), average requisition size (ARS), and peacetime program ratio (PPR). Once an item is read in, the values of these parameters remain the same as long as the item remains in the simulation. As items are created to enter the inventory, the simulation assigns point estimates of these parameters based on the average values of the parameters for the SMGC the created item is entering. Any missing parameters are assigned values in the same manner.

Item prices are also held constant. This assumption is supported by a recent AFLC study showing that item migration is primarily the result of changes in demand, as opposed to changes in price (4:9,11). Prices for new items entering the inventory are based on the empirical distribution of prices in the SMGC the item is entering.

Lead time is an important parameter within the simulation. Lead time often changes as demand changes, since items at different levels of demand fall under different procurement rules. Procurement rules affect the amount of administrative lead time, and therefore affect total lead time. Item migration involves a significant change in demand, so item migration and changes in lead time may often coincide. The simulation provides two options for dealing with lead time. The first is to hold an item's lead time constant throughout the simulation. The second option changes the lead time when an item migrates. The new lead time value is a point estimate based on the average lead time for the SMGC the item is entering. Under either option, created items receive the average lead time for their initial SMGC.

As previously stated, the level of demand for an item changes only when an item migrates. To assign a new dollar value of demand to a migrated item, a distribution of dollar demand values for the new SMGC is needed. A histogram of dollar demand for each SMGC shows a strong resemblance to the exponential distribution. Unfortunately, goodness-of-fit tests on random samples from each SMGC failed for both the exponential and log-normal distributions. Because of the strong resemblance to the exponential, however, dollar demand values were assumed to be exponentially distributed. The lower limit of the SMGC provides the location parameter for the exponential distribution, and the mean is set equal to the average dollar demand value for the SMGC minus the lower limit of the SMGC. Values generated in excess of the upper limit of the SMGC are discarded, and another value is generated.

To summarize the basic assumptions and simplifications of the model, most item parameters are held constant, and new items receive parameter values created deterministically. The demand rate during any quarter is constant. Demand only changes when an items migrates, and then the change is a discrete jump to a different constant demand rate. Only two parameter values are generated stochastically. The SMGC of an item for the next quarter in the simulation comes from a random draw to sample the cumulative transition matrix. This determines item migration. If the item migrates, the second stochasticly generated value is the dollar value of demand within the new SMGC.

Modifications to the Disz Model. The Disz model required several significant modifications to effectively model the dynamic inventory scenario associated with item migration. The original Disz model maintains constant, unchanging demand for the length of the simulation. This means no backorders and no item migration can occur. No differentiation is made between stock purchase and arrival; stock arrives instantly at the end of each procurement cycle. There is no movement of items in and out of the inventory. To alleviate these shortcomings, several new model components were created.

The first modification is a means to generate quarterly item migration. At the start of each quarter, the model compares a standard uniform random number to the row of the transition matrix corresponding to the current SMGC of the item. The range of values within which the random number falls determines the SMGC for the next quarter. If the item migrates, the new level of demand comes from the exponential distribution of demand for the new SMGC, obtained from the inverse transform of the exponential cumulative density function acting upon a standard uniform random number.

The importance of lead time, occurring between stock order and arrival, requires the model to track the days within each quarter. When the reorder level is breached, the model places the order by scheduling the order to arrive at the end of the lead time. Lead time is converted from days to quarters and days, and is added to the current quarter and day to determine the time of arrival. Each day during the simulation the current quarter and day are checked to see if an order is to arrive that day. The average number of days in a quarter is 91.25. To allow the computer program of the model to loop on integer values, the model uses 91 days per quarter. Real days are converted to these slightly longer days by multiplying by 91/91.25.

The length of lead time for some items exceeds the length of time the economic order quantity of stock for those items will last. To deal with this possibility, the reorder level is compared to the assets on hand plus the assets on order. Lead time becomes a "pipeline" of stock on order scheduled to arrive when on hand assets reach the safety level. Each order has its own arrival date, and each day of the simulation all inbound orders are checked to see if an order arrives that day. The model provides for several orders to be inbound at any given time.

Another change to the model involves generating inbound orders of stock when an item enters the simulation. At the beginning of a simulation run, many items in the inventory will have assets below the reorder level and orders due to arrive in the future. The model is modified to determine the dates of order arrival by calculating the times from the start of the simulation through one lead time when, under the current demand rate, the asset level falls to the safety level. These times are the scheduled arrivals of an economic order quantity of stock. The inbound orders raise the level of assets on hand plus assets on order above the reorder level, and the normal order-placing mechanism of the model takes over. If the asset position is at or below the safety level at the start of the simulation, a full order plus any safety level replenishment is added before the simulation begins.

To simulate items entering the inventory, the model must create new items. New items are generated after the simulation has run on the items present in the inventory at the start of the simulation. The number of items generated during each quarter is set equal to the number of items that left the inventory during that quarter to maintain a constant number of items in the inventory. The fifth row of the transition matrix determines the proportion of new items going into each SMGC, and the demand is calculated using the exponential distribution discussed above.

The unit price of the new item comes from the empirical price distribution for the specific SMGC. For the items entering a given SMGC in a given quarter, the first ten percent receive the average of the lowest ten percent of the prices of items in the SMGC. The next ten percent entering receive the average price of the next lowest ten percent of prices in the SMGC, and so on (see Figure 3).

```
                    Actual Items in a Given SMGC
---------- ------------------------------------------------>
!  1st 10%   !  2nd 10%   !  3rd 10%   !  4th 10%   !
!  of items  !  of items  !  of items  !  of items  !
!            !            !            !            !
!  Average   !  Average   !  Average   !  Average   !
!   price    !   price    !   price    !   price    !
!-----!------------!------------!------------!------------->
0     ^            ^            ^            ^           Price
      !            !            !            !
! Price for  ! Price for  ! Price for  ! Price for  !
! 1st 10% of ! 2nd 10% of ! 3rd 10% of ! 4th 10% of !
! new items  ! new items  ! new items  ! new items  !
```

Fig. 3 Assignment of Prices to New Items

This technique allows prices for new items to conform to the empirical distribution of prices for the SMGC without the added complexity of assigning prices based on a random draw from that empirical distribution. Each new item in a given SMGC will have one of ten possible price values. The variation achieved between these these ten values is sufficient to simulate the actual price variation between SMGCs.

The final major modification to the Disz model involves collecting the statistics necessary to analyze item migration within the model: migration patterns, backorders, and items in long supply. The model tabulates migration during each quarter and produces migration tables in the format used by Kennedy (11). Backorder statistics are in several forms. Each day, the asset level is checked. If the level is negative, the absolute value of the asset level is added to the quarterly count of backorder days. This figure is also multiplied by the item price to track the quarterly dollar-weighted backorder days. Backorders are also counted when replenishment stock arrives, since this is the point when maximum backorders exist. The model tracks the total maximum backorders and dollar-weighted maximum backorders occurring in each quarter. Finally, at the end of each quarter in the simulation, items with assets in excess of the Approved Force Aquisition Objective (AFAO) count as items in "long supply." The AFAO is defined for SMGC X as the reorder level plus one economic order quantity plus stock for one year of demand. The AFAO for SMGCs T, P, and M is the reorder level plus the greater of either the economic order quantity or stock for two years of demand (1:81). The number of items in long supply and the dollar value of the excess stock are collected for each quarter.

Model Description

The inventory simulation model developed through this research effort is called MIGSIM. MIGSIM is programmed in FORTRAN 77 and currently runs on the VAX 11/780 Classroom Support Computer (CSC) system at the Air Force Institute of Technology. As is typical of many computer simulations, MIGSIM consists of a main program driving several subroutines which carry out most of the important aspects of the inventory simulation. MIGSIM is compact enough to run using the entire consumables inventory of the San Antonio ALC, about 140,000 items; however, because of the need for multiple runs and heavy utilization of computer resources, MIGSIM currently runs on a ten percent sample of the San Antonio ALC inventory. Ten percent of the items from each SMGC, selected at random, comprise the sample. SMGC X, because of the large number of zero demand items, was split into two groups: zero demand and non-zero demand items. Ten percent of each of those two groups was included in the sample. During the simulation, items have an opportunity to migrate to a different SMGC each quarter.

MIGSIM may be configured to run in three item migration modes. The first is with no item migration, similar to the original Disz model. The second is with instant recognition of item migration. When demand changes and an item migrates, all levels are recomputed immediately with the new item parameters. The third mode includes a one quarter lag in the recognitionn by the inventory management system of a migration and accompanying demand change. For one quarter, the item is managed according to the old level of demand while stock on hand is actually reduced at the new demand level in the new SMGC. This third mode is equivalent to the manner in which AFLC currently treats item migration; an item must exhibit the new demand level for three months (one quarter) before the item is moved to the new SMGC.

The MIGSIM source code listing, thoroughly commented, is contained in Appendix A. For information on the FORTRAN formulation of specific aspects of the simulation model, refer to Appendix A. The following paragraphs present a general discussion of the functions performed by the main program, called MAIN, and each subroutine.

MAIN. MAIN is the central component of MIGSIM. MAIN reads in item data from an external file for each item in the inventory at the start of the simulation. The cumulative transition matrix and table of prices for items entering the inventory are read into arrays. MAIN contains the initial values for the random number generator seeds associated with the two stochastic events in the simulation: migration and the resulting new demand level. Finally, MAIN initializes all statistics collection variables to zero before the simulation starts and writes to a file all output statistics at the end of the simulation.

Subroutine BUYDUE. BUYDUE is the first subroutine to process an inventory item when the item starts the simulation. BUYDUE calls subroutine LEVEL, discussed below, to obtain the reorder level, safety level, and the EOQ; and compares the current asset level to the reorder level. If assets are below the reorder level, BUYDUE establishes a time period equal to lead time, beginning at the item's entry into the simulation. BUYDUE then schedules the necessary EOQ orders of replenishment stock to arrive at the precise times during that time period when, under the current demand rate, the asset level will reach the safety level. For items with long lead times and small EOQs, more than one inbound order may be needed. The amount of stock and time of arrival for each order is stored in an array to be added to stock on hand at the correct time in the simulation. This process accounts for the arrival of orders placed before the simulation begins. The inbound orders raise the asset position above the reorder level before the start of simulated demand.

Subroutine CYCLE. CYCLE is the heart of the actual inventory management simulated in MIGSIM. CYCLE subjects inventory items to up to twelve quarters of demand and provides a quarterly opportunity for item migration. CYCLE carries out the main functions of the DO-62 system -- it calculates levels, orders replenishment stock, and schedules stock arrival. Additionally, CYCLE collects quarterly statistics on backorders, dollars spent on stock, items in long supply, and the actual demand experienced by the inventory.

To model item migration, CYCLE uses the standard uniform random number generator present in FORTRAN on the CSC. Each quarter, a random number is compared to the row of the cumulative transition matrix corresponding to the item's current SMGC. CYCLE determines the smallest column value greater than or equal to the random number, and that column corresponds to the item's SMGC for the next quarter. If the next quarter's SMGC is different from that of the previous quarter (the item has migrated), then CYCLE calls the subroutine GETDEM, discussed below, to get the new demand level. CYCLE then recalculates levels, either immediately or after a one quarter lag, depending on the migration mode.

<u>Subroutine GETDEM</u>. GETDEM generates the new dollar value of demand for items migrating to SMGCs. As described in Section IV.1, the distribution of demand is modeled as exponential. GETDEM uses the resident standard uniform random number generator to drive the inverse transform of the exponential cumulative density function for the new demand value. This process is modified somewhat for items entering SMGC X. Because of the extremely large number of zero demand items in SMGC X, a simple Monte Carlo draw first determines whether the item will have a zero or non-zero demand. If the demand is to be non-zero, CYCLE generates another random number and uses the exponential distribution to determine the exact demand.

<u>Subroutine ADDNEW</u>. Item migration includes items leaving the inventory and new items entering the inventory. ADDNEW creates the new items entering the inventory and assigns parameters to those items. The total number of items to enter the inventory each quarter is set equal to the number that have left the inventory during that quarter. ADDNEW is called after the simulation has run for all items in the original inventory, and ADDNEW proceeds by quarter from the first quarter to the twelfth. So when ADDNEW

prepares to generate new items for a given quarter, the number of items (both original and previously created by ADDNEW) that have left the inventory during that quarter is known precisely. In this manner the number of items in the inventory remains constant, eliminating any confounding effects caused by fluctuations in inventory size. This is also consistent with the assumption of a stationary Markov process.

The proportion of new items entering each SMGC is provided by the transition probabilities for the "IN" category of the Markov process. ADDNEW generates the required number of new items for each SMGC sequentially, first the SMGC X items, then the SMGC T items, and so on. Subroutine GETDEM is called to determine the dollar value of demand based on the SMGC. The technique for assigning parametric values to a new item is also based on the SMGC and was covered in Section IV.1. For items with non-zero demand, ADDNEW calls BUYDUE to set the initial asset level and schedule inbound orders. Items with no demand receive assets on hand equal to fifteen and no inbound orders. (Fifteen is the average asset level for zero demand items in the actual inventory.)

Once the new item has the necessary assets and inbound orders, ADDNEW calls CYCLE, and the simulation begins at the quarter specified by ADDNEW. To insure that the item experiences one quarter of demand in the SMGC specified by

ADDNEW, the possibility of item migration is eliminated for the first quarter a new item is in the inventory.

Subroutine LEVEL. LEVEL provides a single subroutine to execute the computation of the inventory levels maintained by the DO-62 system. LEVEL calls the appropriate functions, discussed below, to determine the safety level and EOQ. The reorder level is set equal to the lead time demand plus safety level.

Functions. Two subroutines perform function calculations. Subroutine SAFLEV calculates the safety level according to the Presutti-Trepp safety level formula used in DO-62. Subroutine EOQ calculates the economic order quantity using the Wilson Lot Size equation specified in DO-62 (1:80-81).

Model Verification

The migration patterns generated by MIGSIM are driven by the cumulative transition matrix discussed earlier in this chapter. The actual migration patterns observed during MIGSIM runs must be verified as conforming to that transition matrix. This is really a check of the mechanics of the model to see if the migration-producing component of MIGSIM is performing as designed.

Verification of migration patterns is accomplished using the Chi-square goodness-of-fit test on the migration tables produced by MIGSIM. Each line of a table is tested individually. The line entry for each SMGC is considered a cell. The total of all cells in a row is multiplied by the transition probability for migrating to each SMGC from the row SMGC. The results of these computations are the expected number of items in each cell. The difference between the actual and expected value for each cell is squared, divided by the expected value for the cell, and the results for each cell in the row are summed to obtain the Chi-square statistic. The Chi-square test with an alpha value of 0.05 was performed on all twelve migration tables produced in the first run under the first treatment. The test showed good overall compliance with the transition matrix. Although a few scattered rows did fail, general performance was excellent. The few failures may be due to the inherent variability introduced by the random number generator. In fact, the alpha value of .05 means a failure rate of about five percent can be expected.

Model Validation

Before any meaningful experimentation can be done with any simulation model, the experimenter must be sure that the output of the model is consistent with the real activity being modeled. For this research effort, MIGSIM must conform reasonably well to the actual workings of the DO-62 system for the results to have any value. Validation of MIGSIM concerns three aspects of the model output. First, the Markov steady state condition of the model calculated from the original estimates of the transition probabilities is compared to the actual inventory composition. Second, inventory performance within the model is compared to actual inventory performance in terms of commit dollars and total demand value. Third, the model is run with an altered transition matrix. The transition probabilities are adjusted to achieve a steady state solution consistent with actual inventory composition. The commit dollars and demand value of this modified simulation are then compared to actual inventory performance.

<u>Steady State Solution</u>. Since MIGSIM is based on the assumption of a stationary Markov process, the model can be solved for the steady state condition. The steady state condition is the proportion of items in each category after a long period of time. MIGSIM, after several quarters of simulation, can be expected to approach this steady state condition in terms of the number of items in each SMGC. The steady state conditions are expressed as a five element row vector and may be determined by solving the following equation:

$$QM=Q$$

where

Q = the steady state row vector
M = the transition matrix from Figure 2

Solving for Q provides the steady state proportions of items in each category shown in Table I (page 50).

Table I Steady State Proportions

SMGC	Proportion of Items
X	0.704765
T	0.149608
P	0.0848103
M	0.0257786
OUT	0.0350385

The existence of "OUT" as a category with a population of items requires special consideration. The assumption of a Markov process implies a fixed population moving between different categories. The transition matrix shows that OUT is a transient state, i.e. no items remain in OUT more than one quarter. In reality, items usually leave the inventory for good, and new items enter. The OUT category is merely a convention to allow for this turnover of items within the Markov framework and has no physical counterpart or interpretation. The actual steady state proportions that would be observed may be calculated by discarding the OUT proportion and normalizing the remaining proportions by dividing by their sum. The results of the normalization and the actual proportion of items in each SMGC in March 1984 is presented in Table II.

Table II

Normalized Steady State vs. Actual SMGC Proportions

SMGC	Normalized Steady State	Actual SMGC Proportions
X	0.7303553	0.78035
T	0.1550403	0.146651
P	0.0878898	0.0594398
M	0.0267146	0.0135567

From Table II it is clear that the model, over the long run, will have a higher percentage of items in the high value categories than was present in the baseline data from March 1984. The difference is not so great that the model would "run away" by drastically altering the make-up of the inventory. However, the larger number of items in SMGC P and M means the simulated total dollar value of demand may grow from its initial value until steady state is reached.

Inventory Performance. For MIGSIM to effectively show the effect of item migration on inventory performance, MIGSIM must have valid annual demand value and quarterly commit dollars as a baseline before item migration is implemented. Without a valid performance baseline, phenomena observed during experimentation cannot be accurately attributed to experimental factors.

The baseline annual demand value and quarterly commit dollars for MIGSIM are obtained by disabling the migration-producing mechanism within MIGSIM. This results in a constant demand rate for each item throughout the simulation. No items migrate out of the inventory, so no new items enter the inventory. MIGSIM is effectively reduced to the Disz model from which it was developed. Run on a ten percent sample of the inventory, MIGSIM with no item migration maintains an annual demand value of a constant 66.5 million dollars, and average quarterly commit dollars of about 16 million dollars. Quarterly commit dollars would be expected to be about one quarter of the annual demand value to support that level of demand. The average quarterly commit dollars shown here conform quite well to this expectation.

Altered transition matrix. Since the transition matrix developed for MIGSIM results in an increased number of items in the upper value SMGCs, an altered transition matrix with a steady state solution similar to the actual inventory composition may be substituted to validate the demand value generating technique within MIGSIM. The annual demand value exhibited by MIGSIM running with such a transition matrix should remain close to the demand value without migration. Such a matrix is shown in Figure 4.

FROM/TO	X	T	P	M	OUT
X	.950000	.012000	0.0	0.0	.038000
T	.042000	.900000	.028000	0.0	.030000
P	.009500	.045500	.908500	.012500	.024000
M	.004731	.001040	.041668	.926699	.025862
IN	.903474	.063613	.026530	.006383	0.0

Fig. 4 Altered Transition Matrix

This matrix was created through iterative manipulation of the original transition matrix to arrive at a steady state solution very close to the original inventory composition. Table III presents the normalized steady state solution compared to the actual inventory.

Table III

Normalized Steady State vs. Actual SMGC Proportions

SMGC	Normalized Steady State, Altered Transition Matrix	Actual SMGC Proportions
X	0.7823361	0.78035
T	0.1441736	0.146651
P	0.0601171	0.0594398
M	0.0133731	0.0135567

MIGSIM was run five times using the altered transition matrix. The full model output is contained in Appendix D. The average annual demand value over the five runs had a mean of 64.8 million dollars and a standard deviation of 2.5 million dollars, quite close to the 66.5 million dollars per year baseline. This reinforces the validity of MIGSIM. The assumed Markov process, when operating with a steady state approaching the actual inventory composition, will maintain a valid level of annual demand in the presence of item migration.

Experimental Design

The primary reason for developing most models is to allow experimentation within the modeled system that cannot be carried out on the real system. The way in which that experimentation is planned is crucial -- the results from a poorly planned experiment may be marginally useful at best. The experiment involving MIGSIM will consist of varying key aspects of the simulation. These areas to be varied were discussed in the last section of Chapter III. They are: (1) the speed with which the DO-62 system recognizes and adjusts to item migration and changing demand, (2) fixed lead time or different lead time for each SMGC, and (3) different values for the implied shortage factor. These are the factors in the experiment.

Factors. The first factor, the recognition time for item migration, has two levels. One is instant recognition of item migration. All inventory levels are recomputed as soon as demand changes, and the item is managed according to its new category. The second level involves a one quarter lag before DO-62 recognizes that the item has migrated. For that quarter, the item is managed according to its old demand rate, while stock is removed at the new demand rate.

The second factor, lead time variation, also has two levels. The first employs fixed lead time, assigned according to SMGC when the item enters the simulation and never changing throughout the simulation. The second level allows lead time to change when the item migrates. In this case, migrating items will receive a lead time equal to the average lead time of the SMGC they are entering.

The third factor is the implied shortage factor. The implied shortage factor determines the amount of safety level present in the inventory. Safety level is an important method for reducing backorders, and could be of use in limiting the backorders resulting from item migration. By using the implied shortage factor as an experimental factor, this analysis investigates the ability of safety level to help control the cost of item migration. The implied shortage factor has two levels. The first is the value of the implied shortage factor used in March 1984. The second is a higher value, implying greater availability of safety level funding.

Treatments. Because of the relatively small number of factors and levels, the experiment uses a full factorial design where all possible combinations of factor levels are subject to simulation. This design results in eight different combinations, or treatments. The different treatments are presented in Table IV.

Table IV

Treatments for Full Factorial Design

Treatment	Migration Recognition	Lead Time	Shortage Factor
1	Instant	Fixed	580
2	Instant	Fixed	680
3	Instant	Varied	580
4	Instant	Varied	680
5	Lag	Fixed	580
6	Lag	Fixed	680
7	Lag	Varied	580
8	Lag	Varied	680

Five simulation runs with different random number seed values will provide repetitions of each of these treatments. Because of the number of runs required and the heavy utilization of computer resources, the model will run on a sample of ten percent of the actual San Antonio ALC inventory. The output statistics for dollar-weighted maximum backorders and the dollar value of excess stock for items in long supply will be the subject of an analysis of variance (ANOVA) to determine the effect of each of the factors on the cost of item migration.

V. Analysis of Results

The MIGSIM computer model was run according to the experimental design discussed in Chapter IV. The output for all runs is contained in Appendix B. Migration tables from the five runs are identical under each treatment, and so are included for only the first treatment. The General Linear Model procedure of the Statistical Analysis System (SAS) provides an analysis of variance (ANOVA) for the output statistics for dollar-weighted maximum backorders per quarter and the dollar value of long supply (15:439). The results for backorders and long supply are presented separately, and provide the foundation for a discussion of the cost of item migration.

Dollar-Weighted Maximum Backorders

Table V presents the average dollar-weighted backorders for the first simulation run under each treatment. Refer to Appendix B for values for runs two through five.

Table V

First Run Dollar-Weighted Maximum Backorders

Migration Recognition	Lead Time	Shortage Factor	Dollar-Weighted Maximum Backorders
Instant	Fixed	580	4,004,060
Instant	Fixed	680	3,995,780
Instant	Varied	580	4,593,480
Instant	Varied	680	4,585,730
Lag	Fixed	580	10,963,200
Lag	Fixed	680	10,945,900
Lag	Varied	580	10,753,100
Lag	Varied	680	10,740,800

Analysis of Variance (ANOVA). The initial ANOVA is of the full factorial design with all possible factor interactions. The design is blocked by run number to compensate for variation caused by the common random number streams. The full model ANOVA table with partial sums of squares, Table VI (page 59), shows that interaction effects are negligible. Of the main effects only the demand information lag and run number account for significant variation in the model.

The significance of the information lag and run number is explored by reducing the model to only the main effects of the information lag and run number. Table VII (page 60) presents the ANOVA table for the reduced model. From Table VII it is clear that the information lag and variation between runs account for all significant variability within the model. The P-values for the partial F tests show that both factors are very important. The R-squared value of 0.97 further shows the model to be very effective in explaining variation of responses. Appendix E contains a plot of predicted values versus residuals which gives no indication of changing variance, so model aptness is confirmed. A plot of ranked residuals, also in Appendix E, supports the underlying assumption of normality. The strength and validity of this model allow meaningful analysis of mean responses for factor levels.

Table VI

Full Model ANOVA Table for Backorders (15:439)

DEPENDENT VARIABLE: AVERAGE DOLLAR-WEIGHTED BACKORDERS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	11	700197417236245	63654310657840
ERROR	28	19432427930265	694015283224
CORRECTED TOTAL	39	719629845166510	

F VALUE	PR > F
91.72	0.0001

R-SQUARE	C.V.	ROOT MSE	AVBMD MEAN
0.972997	9.6470	833076	8635611.50000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
INFO	1	609622561558890	878.40	0.0001
LDTM	1	74730838090	0.11	0.7452
INFO*LDTM	1	2294285461690	3.31	0.0797
LAM	1	3726058090	0.01	0.9421
LAM*INFO	1	385765210	0.00	0.9814
LAM*LDTM	1	21403690	0.00	0.9956
LAM*INFO*LDTM	1	26406250	0.00	0.9951
RUN	4	88201679744335	31.77	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
INFO	1	3892741657711	5.61	0.0250
LDTM	1	289546531	0.00	0.9838
INFO*LDTM	1	13159317360	0.02	0.8915
LAM	1	3726058090	0.01	0.9421
LAM*INFO	1	385765210	0.00	0.9814
LAM*LDTM	1	21403690	0.00	0.9956
LAM*INFO*LDTM	1	26406250	0.00	0.9951
RUN	4	88201679744335	31.77	0.0001

Table VII

Reduced Model ANOVA Table for Backorders (15:439)

DEPENDENT VARIABLE: AVERAGE DOLLAR-WEIGHTED BACKORDERS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	5	697824241303225	139564848260645
ERROR	34	21805603863285	641341290097
CORRECTED TOTAL	39	719629845166510	

F VALUE	PR > F
217.61	0.0001

R-SQUARE	C.V.	ROOT MSE	AVBMD MEAN
0.969699	9.2737	800838	8635611.50000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
INFO	1	609622561558890	950.54	0.0001
RUN	4	88201679744335	34.38	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
INFO	1	609622561558890	950.54	0.0001
RUN	4	88201679744335	34.38	0.0001

Comparison of Mean Responses. The MEANS statement within the SAS General Linear Model procedure provides the Tukey test for mean response differences and Tukey confidence intervals for the difference between mean responses for the two levels of information lag: no lag and one quarter of lag (15:439). The results appear in Table VIII (page 61).

Table VIII

Mean Responses for Backorders (15:439)

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: AVERAGE DOLLAR-WEIGHTED BACKORDERS

ALPHA=.05 DF=34 MSE=6.4E+11
CRITICAL VALUE OF STUDENTIZED RANGE=2.874
MINIMUM SIGNIFICANT DIFFERENCE=514669

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

TUKEY GROUPING	MEAN	N	INFC
A	12539528	20	lag
B	4731695	20	nolag

COMPARISONS SIGNIFICANT AT THE .05 LEVEL
ARE INDICATED BY '***'

INFO COMPARISON	SIMULTANEOUS LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	SIMULTANEOUS UPPER CONFIDENCE LIMIT	
lag - nolag	7293164	7807833	8322502	***

There is clearly a very large difference in the dollar-weighted backorders generated when item migration is instantly recognized compared to a one quarter lag in migration information. A one quarter lag would seem to at least double the amount of backorders. A difference of this magnitude may suggest that a one quarter information lag is not a very realistic factor level. For instance, if the change in demand came from known quantitative requirements, the projected demand rate would be updated before the demand actually occurred. Although the item would not migrate for one quarter, the system would use the updated demand rate to immediately compute the correct order size and reorder level. For the many high demand items falling under the six month minimum buy policy there is a fifty percent chance of placing an order in any quarter, so with a one quarter lag there is a fifty percent chance of placing an incorrect order when migration occurs. Also, a one quarter delay in recognizing a much higher demand level for such an item will in itself cause many backorders, regardless of whether an incorrect order is placed. But although a one quarter information lag may not be entirely realistic, it does illustrate the importance of accurate, timely demand information to inventory support.

The importance of the information lag to dollar-weighted backorders to the exclusion of other factors may be explained by considering size of the demand change associated with migration. Safety level, determined by the implied shortage factor, provides only a margin of extra stock to cover demand variations about a mean level of demand during lead time. Item migration to even the next higher SMGC, creating backorders, often involves at least a ten-fold increase in demand. A change of this magnitude overwhelms any reasonable safety level immediately, rendering safety level an ineffective method for counteracting migration-induced backorders.

The effect of lead time variation is also negligible, and for much the same reason. MIGSIM provides for an increase in lead time of from 50 to 80 days when an item migrates to the next higher SMGC. This adjacent migration is the most common. A change of that size, when compared to the length of lead time itself, is not overly large. Although it will create some shortfall in stock on hand, this shortfall, like safety level, will be dwarfed by the stock shortage resulting from the large demand increase. Additionally, only orders placed after the item migrates will be affected by the change in lead time. Orders already in the pipeline have their own previously scheduled arrival times which will not change.

The lack of effect of varying lead time runs contrary to findings at the Defense Electronic Supply Center. Research there indicated a significant contribution of increasing lead time to the backorders caused by upward migration (18:9-10). Although the evidence presented here does not support the same conclusion at AFLC, the reasoning presented by Smith and Gumbert for the lead time effect is nonetheless compelling (18:9). The reason for the inconsistancy between the two studies may be because of the overpowering effect of the information lag discussed above.

<u>Dollar Value of Long Supply</u>

Tab' ɜ IX (page 64) presents the average dollar value of long supply for the first simulation run under each treatment. Refer to Appendix B for values for runs two through five.

Table IX

First Run Dollar Value of Long Supply

Migration Recognition	Lead Time	Shortage Factor	Dollar Value of Long Supply
Instant	Fixed	580	66,491,500
Instant	Fixed	680	67,184,600
Instant	Varied	580	68,977,100
Instant	Varied	680	69,718,200
Lag	Fixed	580	65,754,000
Lag	Fixed	680	66,400,900
Lag	Varied	580	67,343,400
Lag	Varied	680	68,018,600

Analysis of Variance (ANOVA). The ANOVA for the dollar value of long supply is basically the same as for dollar-weighted maximum backorders. The full factorial model, blocked by run number, showed insignificant interaction effects. The only significant main effects present were those of varying versus constant lead time, the implied shortage factor, and run number. The SAS ANOVA table for the full model, with partial sums of squares, is found in Table X (page 65).

The reduced ANOVA model for the dollar value of long supply contains only the effects of lead time, the implied shortage factor, and run number. The ANOVA table and partial sums of squares for the reduced model make up Table XI (page 66). From the reduced model it becomes clear that both lead time variability and safety level (as determined by the implied shortage factor), after blocking out variation between runs, account for almost all variability

Table X

Full Model ANOVA Table for Long Supply (15:439)

DEPENDENT VARIABLE: AVERAGE VALUE OF LONG SUPPLY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	11	17526311493 98251	1593301044 90750
ERROR	28	10378416629498	370657736768
CORRECTED TOTAL	39	1763009566027749	

F VALUE	PR > F
429.86	0.0001

R-SQUARE	C.V.	ROOT MSE	AVLSD MEAN
0.994113	0.8118	608817	74995992.5000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
INFO	1	108878790250	0.29	0.5921
LDTM	1	47342144306250	127.72	0.0001
INFO*LDTM	1	539702592250	1.46	0.2377
LAM	1	12882136500250	34.75	0.0001
LAM*INFO	1	4010006250	0.01	0.9179
LAM*LDTM	1	3863190250	0.01	0.9194
LAM*INFO*LDTM	1	91506250	0.00	0.9876
RUN	4	1691750322506501	1141.05	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
INFO	1	7962340736	0.02	0.8845
LDTM	1	232714525637	0.63	0.4348
INFO*LDTM	1	2360643465	0.01	0.9370
LAM	1	12882136500250	34.75	0.0001
LAM*INFO	1	4010006250	0.01	0.9179
LAM*LDTM	1	3863190250	0.01	0.9194
LAM*INFO*LDTM	1	91506250	0.00	0.9876
RUN	4	1691750322506501	1141.05	0.0001

Table XI

Reduced Model ANOVA Table for Long Supply (15:439)

DEPENDENT VARIABLE: AVERAGE VALUE OF LONG SUPPLY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	6	1751974603313001	291995767218833
ERROR	33	11034962714748	334392809538
CORRECTED TOTAL	39	1763009566027749	

F VALUE	PR > F
873.21	0.0001

R-SQUARE	C.V.	ROOT MSE	AVLSD MEAN
0.993741	0.7711	578267	74995992.5000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
LDTM	1	47342144306250	141.58	0.0001
LAM	1	12882136500250	38.52	0.0001
RUN	4	1691750322506501	1264.79	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LDTM	1	47342144306250	141.58	0.0001
LAM	1	12882136500250	38.52	0.0001
RUN	4	1691750322506501	1264.79	0.0001

in the dollar value of long supply. The partial F tests show each to be a strong model component, and the R-square value of 0.99 attests to the effectiveness of the reduced model. A plot of predicted versus residual values supports unchanging variance for model aptness, and a plot of ranked residuals confirms that the assumption of normality is valid. Further analysis of mean responses is warranted.

<u>Comparison of Mean Responses</u>. Again, SAS provides the Tukey test for significant differences between mean responses for each level of a given factor. The Tukey confidence interval for the difference between mean responses is also included.

The difference in the dollar value of long supply for constant and varying lead time is shown in Table XII. Both the mean difference and the 95 percent confidence interval show a considerable increase in long supply when lead time varies. The higher safety level associated with a higher implied shortage factor also brings about a higher mean response in the dollar value of long supply, as shown in Table XII (page 68). While the effect of safety level is roughly half that of varying lead time, it is nevertheless significant.

The reason for the considerable effect of lead time changes on long supply involves the direct relationship between lead time and the Approved Force Acquisition Objective (AFAO). A major portion of the AFAO is the reorder level, which in turn is primarily a function of lead time. It is reasonable to expect lead time to fall when demand fails. Less demand means smaller orders, and smaller orders take less processing time and are not subject to as many restrictions to assure competitive purchases.

Table XII

Mean Responses for Long Supply (15:439)

TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLE: AVERAGE VALUE OF LONG SUPPLY

ALPHA=.05 DF=33 MSE=3.3E+1
CRITICAL VALUE OF STUDENTIZED RANGE=2.877
MINIMUM SIGNIFICANT DIFFERENCE=372045

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

TUKEY GROUPING	MEAN	N	LDTM
A	76083905	20	vary
B	73908080	20	fixed

TUKEY GROUPING	MEAN	N	LAM
A	75563490	20	680
B	74428435	20	580

COMPARISONS SIGNIFICANT AT THE .05 LEVEL ARE INDICATED BY '***'

LDTM COMPARISON	SIMULTANEOUS LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	SIMULTANEOUS UPPER CONFIDENCE LIMIT	
vary - fixed	1803780	2175825	2547870	***

LAM COMPARISON	SIMULTANEOUS LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	SIMULTANEOUS UPPER CONFIDENCE LIMIT	
680 - 580	762950	1134995	1507040	***

Production of smaller orders takes less time as well. If lead time falls with demand, not only is the AFAO decreased as a result of declining demand, but it is also decreased by declining reorder level. The lead time "pipeline" becomes shorter and less stock is needed to meet the AFAO. More stock falls above the AFAO and is counted as long supply.

Higher levels of safety stock contribute to an increased dollar value of long supply by increasing the amount of stock on hand when an item migrates downward. Low demand value items are likely to have little or no safety level for any reasonable implied shortage factor value. An item migrating downward takes along its safety level to the lower demand level, where the safety level requirement is reduced or eliminated. The former safety stock is no longer part of the reorder level and so is not needed to meet the AFAO. It only adds to the excess stock over and above the AFAO.

The lack of effect of a demand information lag on the dollar value of long supply can be explained by the size of the drop in demand that occurs when an item migrates downward. Item demand drops considerably, and stock on hand is reduced at a much smaller daily rate, whether or not the inventory management system recognizes that migration has occurred. So in the presence of an information lag, while the reorder level is set too high for one quarter, it is unlikely that the new lower demand rate of the downward migrating item will cause that reorder level to be breached. Only in those instances where the item is already close to the reorder point when demand drops will an incorrect order be generated because of the information lag.

The Cost of Item Migration

Dollar-Weighted Maximum Backorders. Analysis of the results of MIGSIM provides a best and worst case scenario for the dollar-weighted backorders generated by item migration. The best case is when the demand change resulting from item migration is recognized instantly, allowing an average of about 4.7 million dollars worth of backorders per quarter. This measure of backorders does not take into consideration the importance of specific backorders. Certainly backorders of a high-priority part which may ground a weapon system are much more costly to the Air Force than backorders of office supplies. MIGSIM does not measure the priority of a backorder.

The steady state solution for the MIGSIM transition matrix may also influence the cost of migration. The gradual growth in demand value predicted by the steady state solution and observed within MIGSIM means more items may be migrating to higher SMGCs than in the actual inventory system. Increased upward migration would tend to inflate the value of backorders observed.

The dollar-weighted backorders present under the one quarter demand information lag, as mentioned earlier, may not relate to a realistic inventory scenario. Large increases in demand may come from quantitative requirements, which would be known in advance by the system and added to the predicted demand before demand actually changes. But the dramatic increase in backorders resulting from the delay does illustrate the crucial role accurate information on item demand plays in determining the effectiveness of an inventory system. The cost of item migration in terms of dollar-weighted backorders is clearly substantial, even with the most timely information on item demand.

Dollar Value of Long Supply. To effectively gauge the value of long supply caused by item migration, the excess stock present during migration must be compared to the excess stock already in the inventory. The level of existing long supply can be observed from the MIGSIM run with no item migration contained in Appendix C. The average value of that baseline excess stock is about 29 million dollars. Item migration creates 74 to 76 million dollars of long supply depending on the amount of safety level and the variability of lead time. It appears that item migration may be responsible for increasing the value of long supply over 45 million dollars during the twelve quarters of the simulation. If this number is extrapolated from the ten percent inventory sample to the entire inventory, the figure could be roughly 450 million dollars. That is a large amount of money tied up in unnecessary stock -- money that could be used to meet priority requirements elsewhere. The cost of item migration must include this opportunity cost of funds committed to unneeded stock.

VI. Conclusions and Recommendations

Conclusions

Item migration has been shown to exist in inventory systems within the Department of Defense. But though the occurrence of item migration was documented, the full implications of item migration for inventory managers were not explored in depth. No cost was assigned to item migration either in terms of dollars or a decreased ability of the inventory to meet the needs of customers.

This research effort begins to quantify the effects of item migration on the AFLC consumable item inventory. A simplified model of the inventory management system provides a vehicle to measure both the value of backorders generated by items migrating upward and the value of stock in long supply created by items migrating downward. The influence of certain key factors within the inventory management system are analyzed. These factors are the speed with which the system recognizes and reacts to the demand change resulting from item migration, the variability of lead time, and the amount of safety level in the inventory.

It appears that the ability of the inventory system to react quickly to large demand changes is very important in limiting the number of backorders from upward migration. The chance of failing to place a necessary order of replenishment stock or placing too small an order before the system adjusts to the new demand rate greatly exacerbates the problem of backorders. The research investigated only the ability to react once migration occurred, however, not the effect of correctly anticipating item migration before it occurs. On the other hand, reaction time during item migration is not important for downward-migrating items. The sudden drop in demand occuring when an item moves to a lower SMGC makes the breach of the reorder level unlikely, even if the reorder level is calculated from a higher, incorrect demand rate. So incorrect orders of stock seldom result.

Lead time variability seems to have little effect on migration-induced backorders. The large demand change associated with migrating to a higher SMGC may overshadow the extra stock required in the "pipeline" for increased lead time, at least when lead time increases only incrementally as within this model. As mentioned in Chapter IV, this lack of effect runs counter to the findings of Smith and Gumbert at DESC (18:9). The disagreement may be reconciled by realizing that the large information lag effect may render an otherwise valid lead time effect invisible. However, lead time changes have a definite effect on the amount of long supply resulting from downward migration. As lead time decreases, so does the Approved Force Acquisition Objective. Stock that before was filling the lead time "pipeline" is no longer required for that purpose, and adds to the amount of long supply.

The last factor, the implied shortage factor, determines how much safety level is present. Safety level is shown to be ineffective in limiting backorders from item migration. The large demand change associated with upward migration overwhelms the relatively small margin of safety stock. Safety level does influence the value of long supply, for much the same reason as varying lead time. Safety level counts toward the Approved Force Acquisition Objective. At lower demand levels less safety stock is required, and the former safety stock winds up adding to the amount of long supply. The higher the safety level, the more the potential for long supply.

This research effort attempts to put a "price tag" on item migration. The figures arrived at, however, must be couched with the realization that approximations within the model may affect the magnitude of tho cost. The model shows a mean dollar value of maximum backorders of 4.7 million per quarter under the best conditions, i.e. with instant recognition of item migration. This figure may be inflated by the general rise in total demand value for the entire inventory as the model approaches the Markov steady state. But even in light of that fact, it may be safely said that item migration causes large amounts of backorders, and the failure of inventory management to react quickly to changing demand will greatly increase the level of backorders. This is illustrated by the jump to a mean of 12.5 million dollars in backorders per quarter when one quarter is allowed to elapse before the inventory management system recognizes the new demand level.

The value of long supply is less volatile in responding to different levels of the factors influencing it. The mean responses range from about 74 to 76 million dollars worth of stock. While this difference is statistically significant, when compared to the overall amount of long supply it carries less weight. Although reducing safety level would produce a lower value of long supply, the increased backorders resulting from the routine demand fluctuations within SMGCs could greatly outweigh the benefit. The amount of money tied up in this level of long supply is lamentable, but the factors investigated here do not provide a solid basis for attacking the problem. While the effects of varying lead time and safety level pass the significance test, they do not have the magnitude necessary to spawn new management policy.

The cost of item migration shown in the model may be extrapolated to the entire San Antonio ALC inventory. The model was run on a ten percent sample, so multiplying the results by ten indicates the effect on the whole consumables inventory. Item migration may account for at least 47 million dollars in backorders each quarter in just this one ALC, and if similar conditions exist in the other four ALCs, the backorder cost to AFLC becomes greater still. The calculated value of migration-induced long supply at San Antonio ALC is about 450 million dollars over a three year period. Again, if this is similar to the other ALCs, AFLC is experiencing great opportunity cost as a result of item migration. As new weapon systems enter service and the defense budget becomes tighter, the money tied up in long supply will be urgently needed to meet priority requirements. The cost of the long supply shown here may become intolerable.

Recommendations

The research presented here has provided some insight into the movement of items between SMGCs and the impact of that phenomena on the inventory system. The most meaningful finding is that item migration costs money, and good, responsive inventory management can limit that cost. AFLC would be well served by investing resources in ways to quickly recognize the large increases in demand that indicate item migration. The sooner the item is managed according to the new demand level, the fewer the resulting backorders. Accessible, accurate data on projected requirements will greatly aid in this area. The Requirements Data Base initiative, now becoming operational in AFLC, is just the mechanism to provide such data.

The impact of item migration on inventory management policies must also be considered. This research shows that much of the long supply present is the result of downward migration. Any action taken to evaluate or prevent long supply must be directed at downward-migrating items. Minimum buy policies may also be confounded by item migration. Any increase in the minimum buy will increase the average size of the inventory, and the resulting extra stock will further increase the amount of long supply from downward migration.

While answering some questions, this research has also uncovered new questions. Analysis of the characteristics of items in each SMGC shows great disparity within SMGC X. The overwhelming majority of X items have no demand. The parameters of the zero demand items are far different from their positive demand counterparts in SMGC X, yet all are managed as low value items. For instance, the prices for zero demand items in general are much higher than for other X items. Since zero demand items make up such a large part of the inventory, the nature of these items should be more thoroughly explored. It may be interesting to know where these items originated, how long they have had no demand, and the probability of experiencing demand in the future.

Finally, the manner in which items migrate should be investigated further. The model used for this research gave all items in an SMGC an equal chance of migrating. This was necessary since the only data available provided only a count of items moving between SMGCs. It may well be that items tend more to migrate between the upper range of one

SMGC and the lower range of the next highest SMGC. Given the breadth of the upper SMGCs such a jump could still involve a large demand change, but not the average ten-fold increase for upward migration currently experienced in the simulation. Better understanding of the specific origins and destinations of migrating items will allow more accurate modeling of migration in the future.

Appendix A: MIGSIM FORTRAN Source Code

```
c      Program MIGSIM
c      Variables:
c      cat    = SMGC (X=1,T=2,P=3,M=4,OUT=5)
c      q      = economic order quantity
c      sl     = safety level
c      rol    = reorder level
c      leadti = lead time (days)
c      ip     = inventory position (on hand plus due in)
c      pmdr   = program monthly demand rate
c      demand = dollar value of annual demand
c      lam    = implied shortage factor
c      astot  = total on hand assets
c      price  = actual unit price
c      mad    = mean absolute deviation of demand
c      ars    = average requisition size
c      ppr    = peacetime program ratio
c      lag    = is there a one quarter information lag? (T/F)
c      varldt = does lead time vary by SMGC? (T/F)
c      migsd  = seed value for migration generator
c      demsd  = seed value for demand generator
c      av**   = average of quarterly values for
c               output statistic
c
c      Arrays:
c      mgcnt  = migration tables
c      bkord  = backorder days
c      bkmax  = maximum backorders
c      bkdol  = dollar-weighted backorder days
c      bkmxdl = dollar-weighted maximum backorder days
c      longsp = number of items in long supply
c      longdl = dollar value of long supply
c      demval = total annual demand value
c      comdol = quarterly commit dollars
c      qtrdue = quarter due of inbound order
c      daydue = day due of inbound order
c      order  = size of inbound order
c      mprob  = cumulative transition matrix
c      madval = average mad value for each SMGC
c      arsval = average ars value for each SMGC
c      prval  = empirical price distribution for each SMGC
c
       program migsim
       integer i,j,k,cat,qtr,mgcnt(12,5,5),astot,
      &bkord(12),bkmax(12),ldtval(4),qtrdue(6),
      &daydue(6),order(6),q,rol,leadti,run,ip,
      &longsp(12)
       integer migsd,demsd
```

```
      real price,pmdr,demand,mprob(1:5,0:5),mad,ars,
     &ppr,madval(4),arsval(4),comdol(12),bkdol(12),
     &bkmxdl(12),prval(0:4,0:10),lam,longdl(12),demval(12),
     &avbd,avbdd,avbm,avbmd,avls,avlsd,avcd,avdem
      character*5 info,ldtm
      character*2 labl(5)
      logical new,lag,varldt
      data (madval(i),i=1,4)/4.04,9.51,16.94,94.45/,
     &     (arsval(i),i=1,4)/1.58,1.77,2.12,3.54/,
     &     (ldtval(i),i=1,4)/336,373,410,545/,
     &     (labl(i),i=1,5)/' X',' T',' P',' M','IN'/
      open(unit=8,file='for008.dat',status='old')
      open(unit=9,file='for009.dat',status='old')
      open(unit=10,file='for010.dat',status='old')
      open(unit=12,file='for012.dat',status='new')
      open(unit=14,file='for014.dat',status='new')
      open(unit=15,file='for015.dat',status='new')
c
c     unit 8  - file of factor levels, seeds, and run number
c     unit 9  - file of cumulative transition matrix
c     unit 10 - fils of SMGC price distributions
c     unit 12 - output of migration reports
c     unit 14 - output of migration tables formatted
c               for statistical analysis
c     unit 15 - output of inventory performance formatted
c               for statistical analysis
c
      do 20 i=1,5
         read(9,109)(mprob(i,j),j=0,5)
 20   continue
 109  format(6(f8.0,1x))
      do 25 i=0,4
         read(10,110)(prval(i,j),j=0,5)
         read(10,210)(prval(i,j),j=6,10)
 25   continue
 110  format(6(f8.0,1x))
 210  format(5(f8.0,1x))

 1    continue
      read(8,108,end=1000) lag,varldt,lam,migsd,
     &                     demsd,run
c     read in simulation parameters for this run
 108  format(l1,1x,l1,1x,f4.0,1x,2(i4,1x),i2)
      if (lag) then
         info='  lag'
      else
         info='nolag'
      endif
```

```
      if (varldt) then
         ldtm=' vary'
      else
         ldtm='fixed'
      endif

      do 5 i=1,12
         bkord(i)=0
         bkdol(i)=0
         bkmax(i)=0
         bkmxdl(i)=0
         longsp(i)=0
         longdl(i)=0
         demval(i)=0
         comdol(i)=0
         do 10 j=1,5
            do 15 k=1,5
               mgcnt(i,j,k)=0
 15         continue
 10      continue
 5    continue
      new=.false.

      write(12,113)
      if (lag) then
         write(12,114)
      else
         write(12,115)
      endif
      if (varldt) then
         write(12,116)
      else
         write(12,117)
      endif
      write(12,120) lam
      write(12,118) run
      write(12,119) migsd,demsd
c     write header for run output
 113  format(' '/' '/' '/' ','Model output'/)
 114  format(' ','One quarter information lag')
 115  format(' ','No information lag')
 116  format(' ','Variable lead time')
 117  format(' ','Constant lead time')
 118  format(' ','Run number ',i2)
 119  format(' ','migsd= ',i4/' ','demsd= ',i4/)
 120  format(' ','Implied shortage factor= ',f4.0)

      open(unit=11,file='for011.dat',status='old')
c     unit 11 = file of inventory items
 2    continue
      read(11,111,end=900) price,astot,ppr,pmdr,l[illegible]d[illegible]i,
     &                     mad,ars
```

```
      if (price.eq.0.0) goto 2
      demand=price*pmdr*12.0
c     categorize into SMGCs
      if (demand.ge.0.and.demand.le.500.0) then
         cat=1
      endif
      if (demand.gt.500.0.and.demand.le.5000.0) then
         cat=2
      endif
      if (demand.gt.5000.0.and.demand.le.50000.0) then
         cat=3
      endif
      if (demand.gt.50000.0) then
         cat=4
      endif
      if (ppr.eq.0) ppr=1.0
      leadti=ldtval(cat)
      leadti=nint((leadti/365.0)*364.0)
      if (mad.eq.0) mad=madval(cat)
      if (ars.eq.0) ars=arsval(cat)
      qtr=1
      if (demand.ne.0) then
         call buydue(price,astot,ppr,pmdr,leadti,mad,ars,
     &                   qtrdue,daydue,order,q,rol,lam,new,
     &                   comdol,ip,qtr,cat)
      else
         ip=astot
         q=0
         rol=0
         do 35 i=1,6
            order(i)=0
            qtrdue(i)=0
            daydue(i)=0
 35      continue
      endif
      call cycle(qtr,cat,mgcnt,mprob,price,astot,ppr,
     &           pmdr,leadti,mad,ars,demand,migsd,demsd,
     &           madval,arsval,bkord,bkdol,bkmax,bkmxdl,
     &           comdol,qtrdue,daydue,order,q,rol,new,lag,
     &           varldt,lam,longsp,longdl,demval,ip,ldtval)
      goto 2
 900  continue
      call addnew(mgcnt,mprob,ldtval,prval,madval,arsval,
     &            migsd,demsd,bkord,bkdol,bkmax,bkmxdl,
     &            comdol,longsp,longdl,demval,
     &            lag,varldt,lam)
      do 920 i=1,12
         write(12,121) i
         do 910 j=1,5
            write(12,112) labl(j),(mgcnt(i,j,k),k=1,5)
            write(14,141) info,ldtm,lam,run,i,j,
     &                    (mgcnt(i,j,k),k=1,5)
```

```
 910      continue
          write(12,500)
 920   continue
c      compute average of quarterly stats
       avbd=0
       avbdd=0
       avbm=0
       avbmd=0
       avls=0
       avlsd=0
       avcd=0
       avdem=0
       do 930 i=1,12
          avbd=avbd+bkord(i)/12.
          avbdd=avbdd+bkdol(i)/12.
          avbm=avbm+bkmax(i)/12.
          avbmd=avbmd+bkmxdl(i)/12.
          avls=avls+longsp(i)/12.
          avlsd=avlsd+longdl(i)/12.
          avcd=avcd+comdol(i)/12.
          avdem=avdem+demval(i)/12.
 930   continue
       write(12,212)
       do 960 i=1,12
          write(12,312) i,bkord(i),bkdol(i),
      &                 bkmax(i),bkmxdl(i)
 960   continue
       write(12,313)
       write(12,314) avbd,avbdd,avbm,avbmd
       write(12,500)
       write(12,412)
       do 970 i=1,12
          write(12,413) i,longsp(i),longdl(i),comdol(i),
      &                 demval(i)
 970   continue
       write(12,313)
       write(12,414) avls,avlsd,avcd,avdem
       write(15,151) info,ldtm,lam,run,avbd,avbdd,avbm,avbmd,
      &              avls,avlsd,avcd,avdem
       close(11)
       goto 1
c      get next item
 111   format(f11.0,1x,i8,1x,f5.0,1x,f10.0,1x,
      &       i5,1x,f11.0,1x,f7.0)
 112   format(' ',a2,3x,5(i8,2x))
 121   format(' ','Quarter ',i2/
      &       ' ','FROM/TO    X',9x,'T',9x,'P',9x,
      &       'M',8x,'OUT')
 141   format(' ',2(a5,1x),f4.0,1x,3(i2,1x),5(i6,1x))
 151   format(' ',2(a5,1x),f4.0,1x,i2,1x,4(e12.6,1x)/
      &       ' ',4(e12.6,1x))
```

```
212  format(' ','qtr bkord-days',4x,'bkord-day$',3x,
    &        'bkord-max',4x,'bkord-max$')
312  format(' ',i3,1x,2(i10,2x,e12.6,2x))
313  format(' ','Average values')
314  format(' ',3x,2(e11.6,2x,e12.6,1x))
412  format(' ','qtr long items',6x,'long $',7x,
    &        'commit$',7x,'demval$')
413  format(' ',i3,1x,i8,2x,2(e12.6,2x),e12.6)
414  format(' ',4x,f8.1,2x,2(e12.6,2x),e12.6)
500  format(' '/)
1000 continue
     close(8)
     close(9)
     close(10)
     close(12)
     close(14)
     close(15)
     stop
     end

c    Subroutine CYCLE
c    Variables not already defined:
c    pmig   = random number for determining migration
c    afao   = approved force acquisition objective
c    daydem = daily demand
c    rip, rastot = ip, astot converted to reals
c
     subroutine cycle(qtr,cat,mgcnt,mprob,price,astot,
    &                 ppr,pmdr,leadti,mad,ars,demand,
    &                 migsd,demsd,madval,arsval,bkord,
    &                 bkdol,bkmax,bkmxdl,comdol,qtrdue,
    &                 daydue,order,q,rol,new,lag,varldt,
    &                 lam,longsp,longdl,demval,ip,ldtval)
     integer i,j,k,cat,day,qtr,mgcnt(12,5,5),astot,leadti,
    &newcat,bkord(12),bkmax(12),qtrdue(6),daydue(6),
    &order(6),q,rol,sl,longsp(12),ip,ldtval(4)
     integer migsd,demsd
     real pmig,mprob(1:5,0:5),price,ppr,pmdr,mad,ars,
    &demand,madval(4),arsval(4),bkdol(12),bkmxdl(12),
    &comdol(12),rastot,olddem,lam,longdl(12),demval(12),
    &rip,daydem,afao
     logical new,lag,varldt,found
     rastot=float(astot)
     rip=float(ip)
10   continue
```

```
c     generate item migration
      if (qtr.le.12.and.cat.ne.5) then
         if (.not.new) then
            pmig=ran(migsd)
            do 15 k=1,5
               if (pmig.ge.mprob(cat,k-1).and.pmig.lt.
     &               mprob(cat,k)) then
                  newcat=k
               endif
 15         continue
            mgcnt(qtr,cat,newcat)=mgcnt(qtr,cat,newcat)+1
         else
            newcat=cat
            mgcnt(qtr,5,newcat)=mgcnt(qtr,5,newcat)+1
            new=.false.
         endif
         if (newcat.ne.5) then
            olddem=demand
            if (cat.ne.newcat) then
               if (varldt) leadti=
     &                     nint((ldtval(newcat)/365.)*364.)
c              get new demand level
               call getdem(newcat,demsd,demand)
               pmdr=(demand/price)/12.0
               if (olddem.eq.0.or..not.lag) then
                  if (ars.eq.0) ars=arsval(newcat)
                  if (mad.eq.0) mad=madval(newcat)
c                 compute levels for instant reaction
c                 to item migration
                  call level(newcat,demand,q,sl,rol,price,
     &                       pmdr,ppr,mad,leadti,ars,lam)
               endif
            endif
            daydem=(pmdr*12.0)/364.0
            do 20 day=1,91
               do 25 i=1,6
                  if (qtrdue(i).eq.qtr.and.daydue(i).eq.day)
     &               then
c                    when order arrives count max backorders
                     if (rastot.lt.0) then
                        bkmax(qtr)=
     &                       bkmax(qtr)+nint(abs(rastot))
                        bkmxdl(qtr)=
     &                       bkmxdl(qtr)+abs(rastot*price)
                     endif
                     rastot=rastot+order(i)
                     order(i)=0
                     qtrdue(i)=0
                     daydue(i)=0
                  endif
 25            continue
```

```
                  rastot=rastot-daydem
                  rip=rip-daydem
c                 count backorder days
                  if (rastot.lt.0) then
                     bkord(qtr)=bkord(qtr) + nint(abs(rastot))
                     bkdol(qtr)=bkdol(qtr)+ abs(price*rastot)
                  endif
                  if (rip.le.rol) then
c                 place and schedule order
                     i=1
                     found=.false.
 35                  continue
                     if(i.le.6.and..not.found) then
                        if (order(i).eq.0) then
                           order(i)=q+(rol-nint(rip))
                           qtrdue(i)=qtr+int(leadti/91.)+
     &                           int(day/91.0+leadti/91.0 -
     &                           int(leadti/91.))
                           daydue(i)=1+mod(leadti+day,91)
                           comdol(qtr)=
     &                           comdol(qtr)+(order(i)*price)
                           rip=rip+order(i)
                           found=.true.
                        endif
                        i=i+1
                        goto 35
                     endif
                  endif
 20            continue

               if (cat.ne.newcat.and.lag) then
c              compute levels after one quarter lag
                  call level(newcat,demand,q,sl,rol,price,
     &                     pmdr,ppr,mad,leadti,ars,lam)
               endif

            endif

            cat=newcat
            demval(qtr)=demval(qtr)+demand
c           count items and value of long supply
            if (cat.eq.1) then
               afao=rol+q+(pmdr*12.0)
            else
               afao=rol+amax1(float(q),(pmdr*24.0))
            endif
            if (rip.gt.afao) then
               longsp(qtr)=longsp(qtr)+1
               longdl(qtr)=longdl(qtr)+price*(rip-afao)
            endif
```

```
            qtr=qtr+1
            goto 10
         endif
         astot=nint(rastot)
         ip=nint(rip)
         return
         end


c        Subroutine ADDNEW
c        Variables not already defined
c        out    = number of items leaving in a quarter
c        totlin= number of items entering in a quarter
c        fracdn= fraction of items to enter a SMGC that have
c                already entered
c        numin = number of items to enter a SMGC
         subroutine addnew(mgcnt,mprob,ldtval,prval,madval,
     &                  arsval,migsd,demsd,bkord,bkdol,
     &                  bkmax,bkmxdl,comdol,longsp,longdl,
     &                  demval,lag,varldt,lam)
         real mprob(1:5,0:5),prval(0:4,0:10),madval(4),
     &arsval(4),bkdol(12),bkmxdl(12),comdol(12),longdl(12),
     &demval(12),lam
         integer ldtval(4),mgcnt(12,5,5),bkord(12),bkmax(12),
     &longsp(12)
         integer migsd,demsd
         real fracdn,price,demand,pmdr,ppr,j,mad,ars
         integer qtr,cat,i,k,totlin,astot,leadti,sl,rol,q,
     &qtrdue(6),daydue(6),order(6),qstart,out,ip,ii,
     &numin,catst
         logical found,new,lag,varldt
         do 50 qtr=1,12
            out=0
c           count items that left SMGC
            do 45 k=1,4
               out=out+mgcnt(qtr,k,5)
 45         continue
            totlin=out
            if (totlin.gt.0) then
               do 40 cat=1,4
c                 calculate number to enter each SMGC
                  numin=nint(float(totlin)*(mprob(5,cat)-
     &                  mprob(5,cat-1)))
                  if (numin.eq.0) numin=1
                  do 30 i=1,numin
c                    track how many have entered already
                     fracdn=float(i)/float(numin)
                     j=0.1
                     found=.false.
 20                  continue
```

```
                  if (j.le.1.0001.and.not(found)) then
c                    assign price based on what fraction has
c                    already entered
                     if (fracdn.ge.(j-0.1).and.fracdn.lt.j)
     &                  then
                        found=.true.
c                       get demand level
                        call getdem(cat,demsd,demand)
                        ppr=1.0
                        leadti=
     &                     nint((ldtval(cat)/365.0)*364.0)
c                       assign item parameters
                        if (demand.eq.0) then
                           price=prval(0,nint(j*10.))
                           pmdr=0.0
                           mad=0.0
                           ars=0.0
                           q=0
                           sl=0
                           rol=0
                           astot=15
                           ip=astot
                           comdol(qtr)=
     &                        comdol(qtr)+astot*price
                           do 25 ii=1,6
                              order(ii)=0
                              daydue(ii)=0
                              qtrdue(ii)=0
 25                        continue
                        else
                           price=prval(cat,nint(j*10.))
                           pmdr=(demand/price)/12.0
                           mad=madval(cat)
                           ars=arsval(cat)
                           new=.true.
                           call buydue(price,astot,ppr,
     &                          pmdr,leadti,mad,ars,qtrdue,
     &                          daydue,order,q,rol,lam,new,
     &                          comdol,ip,qtr,cat)
                        endif
                        qstart=qtr
                        catst=cat
                        new=.true.
                        call cycle(qstart,catst,mgcnt,mprob,
     &                       price,astot,ppr,pmdr,leadti,
     &                       mad,ars,demand,migsd,demsd,
     &                       madval,arsval,bkord,bkdol,
     &                       bkmax,bkmxdl,comdol,qtrdue,
     &                       daydue,order,q,rol,new,lag,
     &                       varldt,lam,longsp,longdl,
     &                       demval,ip,ldtval)
                     endif
```

```
                    j=j+0.1
                    goto 20
                 endif
 30           continue
 40        continue
        endif
 50   continue
      return
      end

c     Subroutine BUYDUE
c     Variables not already defined:
c     duein  - number of days before order is due in
c              from start of item in simulation
c     pcp    - procurement cycle period
c     numord - number of orders to be scheduled
c
      subroutine buydue(price,astot,ppr,pmdr,leadti,mad,ars,
     &                       qtrdue,daydue,order,q,rol,lam,new,
     &                       comdol,ip,qtr,cat)
      real price,ppr,pmdr,mad,ars,lam,comdol(12),demand
      integer astot,leadti,qtrdue(6),daydue(6),order(6),
     &sl,q,rol,duein(6),ip,qtr,cat,pcp,i,numord
      logical new
      demand=price*pmdr*12.0
      call level(cat,demand,q,sl,rol,price,pmdr,ppr,
     &              mad,leadti,ars,lam)
      pcp=nint(q/(pmdr*12.0/364.0))
      if (new) then
         astot=q+sl
         comdol(qtr)=comdol(qtr)+price*astot
      else
         if (astot.le.sl) astot=q+sl
      endif
      ip=astot
      do 10 i=1,6
         duein(i)=0
         order(i)=0
         qtrdue(i)=0
         daydue(i)=0
 10   continue
c     see if an order is needed within lead time
      duein(1)=nint((astot-sl)/(pmdr*12.0/364.0))
      if (duein(1).lt.leadti) then
c     see how many orders needed
         numord=int((leadti-duein(1))/pcp)
         if (numord.gt.0) then
            if(new) comdol(qtr)=comdol(qtr)+numord*q*price
```

```
            do 20 i=1,numord
c              calculate number of days until each
c              order is due
               duein(i+1)=duein(1) + i*pcp
 20         continue
         endif
         do 30 i=1,(numord+1)
c           convert days to due date
            order(i)=q
            ip=ip+q
            qtrdue(i)=qtr+int(duein(i)/91.)
            daydue(i)=1+mod(duein(i),91)
 30      continue
      endif
      return
      end

      subroutine getdem(cat,demsd,demand)
      integer cat,demsd*4
      real demand,rnum1,rnum2
      if (cat.eq.1) then
c     determine zero or non-zero demand
         rnum1=ran(demsd)
         if (rnum1.le.0.26) then
c     determine demand level for non-zero demand
 5          continue
            rnum2=ran(demsd)
            demand=50.-96.4*log(rnum2)
            if (demand.gt.500.) goto 5
         else
            demand=0.0
         endif
      endif
      if (cat.eq.2) then
 10      continue
         rnum1=ran(demsd)
         demand=-1366.74*log(rnum1) +500.01
         if (demand.gt.5000.) goto 10
      endif
      if (cat.eq.3) then
 15      continue
         rnum1=ran(demsd)
         demand=-10259.81*log(rnum1) +5000.01
         if (demand.gt.50000.) goto 15
      endif
      if (cat.eq.4) then
         rnum1=ran(demsd)
         demand=-170375.09*log(rnum1) +50000.01
      endif
      return
      end
```

```
      subroutine level(cat,demand,q,sl,rol,price,pmdr,ppr,
     &                    mad,leadti,ars,lam)
      integer cat,q,sl,rol,leadti,size
      real demand,price,pmdr,ppr,mad,ars,lam
c     determine order size for correct order cost
      if (cat.eq.4) then
         size=2
      else
         size=1
      endif
      if (demand.eq.0) then
         q=0
         sl=0
         rol=0
      else
         call eoq(q,size,price,pmdr)
         call saflev(sl,ppr,mad,leadti,q,ars,pmdr,price,lam)
         rol=sl+nint(0.499+float(leadti)*pmdr*12.0/364.0)
         if (rol.eq.0) rol=1
      endif
      return
      end

      subroutine saflev(sl,ppr,mad,leadti,q,ars,
     &                    pmdr,price,lam)
      real ppr,mad,ars,pmdr,price,hc,lam,theta,k,rlead,
     &     slr,slmax1,slmax2
      integer leadti,q,size,sl
      rlead=float(leadti)
      hc=.17
      theta=(ppr**.85)*.5945*mad*(.82375+(.42625*rlead))
      if (theta.le.0.) theta=0.0001
      if(lam.eq.0.or.ars.eq.0.or.theta.eq.0.or.q.eq.0) then
         print *,q,price,pmdr,ars,theta
         stop
      endif
      k=(-.707)*alog((2.*sqrt(2.)*hc*q*price)/
     &  ((lam/ars)*theta*
     &  (1-exp((-sqrt(2.)*q)/theta))))
      slr=k*theta
      slmax1=rlead*(pmdr*12.0)/364.
      slmax2=3.*theta
      if (slr.gt.slmax1) slr=slmax1
      if (slr.gt.slmax2) slr=slmax2
      if (slr.lt.0.) slr=0.
      sl=nint(slr)
      return
      end
```

```
subroutine eoq(q,size,price,pmdr)
real price,pmdr,hc,oc(2),eoqyr
integer size,i,q
data (oc(i),i=1,2)/345.54,608.30/,hc/.17/
eoqyr=sqrt((2.*oc(size))/(hc*price*pmdr*12.))
if (eoqyr.le.0.5) eoqyr=0.5
if (eoqyr.gt.3.0) eoqyr=3.0
q=nint(eoqyr*pmdr*12.0)
if (q.eq.0) q=1
return
end
```

Appendix B: MIGSIM Output Reports

Model output

No information lag
Constant lead time
Implied shortage factor= 58C.
Run number 1
migsd= 9905
demsd= 7415

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10245	137	14	2	402
T	85	1825	63	1	55
P	8	32	742	11	29
M	0	0	11	168	9
IN	447	31	13	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10194	143	10	0	438
T	91	1833	54	0	47
P	10	40	758	22	13
M	2	0	8	171	4
IN	454	32	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10168	144	25	4	410
T	92	1836	66	0	54
P	4	33	773	14	19
M	0	0	13	180	3
IN	439	31	13	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10136	128	15	3	421
T	76	1839	84	0	45
P	11	34	818	15	12
M	0	0	9	185	7
IN	438	31	13	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10066	141	15	3	436
T	71	1849	62	0	50
P	6	49	842	15	27
M	2	0	15	187	2
IN	464	33	14	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10009	153	14	0	433
T	79	1870	67	1	55
P	11	41	854	15	27
M	0	0	5	199	4
IN	469	33	14	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	9580	139	16	4	429
T	87	1883	63	0	64
P	9	42	865	13	25
M	0	0	8	208	2
IN	469	33	14	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	9966	148	20	2	409
T	82	1866	85	1	63
P	8	38	885	8	27
M	1	0	3	220	4
IN	4[illegible]	32	13	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	9937	128	17	2	427
T	88	1866	69	0	61
P	5	35	939	7	20
M	6	2	7	213	6
IN	464	33	14	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	9974	132	14	1	379
T	85	1849	77	0	53
P	3	32	969	29	13
M	2	1	16	202	4
IN	406	29	12	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	9896	129	15	1	429
T	78	1643	52	0	70
P	5	39	1011	15	18
M	2	1	9	212	11
IN	477	34	14	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	9839	169	9	1	440
T	93	1843	58	0	52
P	7	51	997	17	29
M	2	1	10	213	5
IN	474	33	14	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2942031	0.239700E+08	37	0.539839E+04
2	10283039	0.103940E+09	135	0.547416E+05
3	25318113	0.262752E+09	16269	0.874761E+06
4	45725105	0.468016E+09	170464	0.180702E+07
5	59392070	0.657345E+09	278224	0.432923E+07
6	72566952	0.800335E+09	610511	0.652220E+07
7	71387379	0.755219E+09	424163	0.488447E+07
8	76820080	0.787362E+09	567692	0.668967E+07
9	82777372	0.643522E+09	663296	0.673289E+07
10	56064078	0.589930E+09	635084	0.404424E+07
11	70996914	0.679970E+09	464729	0.737136E+07
12	74435691	0.691572E+09	672514	0.473270E+07
Average values				
	.540591E+08	0.538669E+09	.375260E+06	0.400406E+07

qtr	long items	long $	commit$	demval$
1	6742	0.341338E+08	0.332451E+08	0.695378E+08
2	6810	0.412534E+08	0.209364E+08	0.694906E+08
3	6890	0.467096E+08	0.345610E+08	0.716015E+08
4	6949	0.504361E+08	0.236577E+08	0.742740E+08
5	7014	0.611112E+08	0.382096E+08	0.756709E+08
6	7083	0.674600E+08	0.240158E+08	0.779703E+08
7	7207	0.710524E+08	0.371172E+08	0.808892E+08
8	7250	0.724052E+08	0.235827E+08	0.832453E+08
9	7358	0.723584E+08	0.353077E+08	0.835426E+08
10	7387	0.881232E+08	0.305129E+08	0.840625E+08
11	7480	0.927807E+08	0.341703E+08	0.860210E+08
12	7584	0.100074E+09	0.311343E+08	0.851144E+08
Average values				
	7146.2	0.664915E+08	0.305375E+08	0.784517E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 2
migsd= 6057
demsd= 2873

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10209	129	18	2	442
T	91	1826	58	0	54
P	5	38	746	19	14
M	0	0	5	180	3
IN	463	33	14	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10203	123	17	1	424
T	82	1828	71	0	45
P	6	39	772	12	12
M	0	0	6	194	4
IN	438	31	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10144	147	17	1	420
T	89	1816	69	2	45
P	5	37	804	15	14
M	1	0	8	194	7
IN	439	31	13	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10132	133	8	1	404
T	79	1825	80	0	47
P	7	41	824	15	24
M	1	0	7	205	6
IN	434	31	13	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10074	145	14	2	418
T	72	1834	72	0	52
P	10	38	847	21	16
M	1	0	12	202	9
IN	447	31	13	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10043	129	22	1	409
T	83	1835	71	1	58
P	7	51	854	25	21
M	1	0	8	213	6
IN	446	31	13	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	9986	137	14	0	443
T	88	1847	68	0	43
P	7	37	889	17	18
M	0	0	6	231	6
IN	461	32	14	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	9954	132	19	1	436
T	88	1845	68	0	52
P	12	44	902	19	14
M	2	0	6	231	12
IN	464	33	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	9943	113	15	2	447
T	83	1847	67	0	57
P	2	44	926	16	21
M	3	1	8	233	9
IN	482	34	14	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	9908	143	13	2	447
T	103	1829	59	0	48
P	8	38	940	17	27
M	1	0	9	240	4
IN	474	33	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	9937	127	10	1	419
T	90	1829	68	1	55
P	4	36	956	13	26
M	0	0	11	246	5
IN	456	32	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	9932	115	15	4	421
T	78	1820	75	1	50
P	7	44	970	21	16
M	0	0	10	245	9
IN	448	32	13	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493089	0.293810E+08	73	0.199815E+05
2	11722361	0.145336E+09	823	0.290168E+05
3	26489305	0.340766E+09	61675	0.843654E+06
4	49730611	0.593263E+09	205417	0.260116E+07
5	75639811	0.734999E+09	355939	0.519244E+07
6	123538710	0.784006E+09	966418	0.726650E+07
7	173240063	0.874554E+09	446665	0.638217E+07
8	225291608	0.926298E+09	762510	0.579085E+07
9	218640010	0.104794E+10	4669590	0.100400E+08
10	69582957	0.876482E+09	592492	0.968130E+07
11	78556698	0.745760E+09	525158	0.672158E+07
12	95760217	0.776470E+09	690134	0.661612E+07
Average values				
	.958905E+08	0.656271E+09	.773091E+06	0.509873E+07

qtr	long items	long $	commit$	demval$
1	6771	0.349090E+08	0.386279E+08	0.717272E+08
2	6826	0.406775E+08	0.195038E+08	0.730873E+08
3	6880	0.578157E+08	0.347410E+08	0.697890E+08
4	6959	0.625205E+08	0.206958E+08	0.694410E+08
5	7041	0.713703E+08	0.345428E+08	0.687841E+08
6	7137	0.760535E+08	0.316050E+08	0.736257E+08
7	7222	0.819278E+08	0.320156E+08	0.742770E+08
8	7304	0.822831E+08	0.291913E+08	0.777732E+08
9	7405	0.903643E+08	0.306489E+08	0.754772E+08
10	7457	0.938165E+08	0.269148E+08	0.769444E+08
11	7512	0.907711E+08	0.288854E+08	0.783776E+08
12	7607	0.961311E+08	0.335613E+08	0.818653E+08
Average values				
	7176.8	0.732200E+08	0.300778E+08	0.742641E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 3
migsd= 9745
demsd= 3447

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10225	141	10	0	421
T	89	1829	63	0	48
P	4	26	767	5	20
M	0	1	6	175	6
IN	447	31	13	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10193	126	7	1	438
T	85	1836	72	0	38
P	6	39	792	8	14
M	0	0	11	170	2
IN	444	31	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10125	144	13	1	445
T	82	1817	77	1	55
P	7	42	806	16	24
M	0	0	9	169	4
IN	477	34	14	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10119	134	13	3	422
T	100	1816	63	0	58
P	9	43	831	10	26
M	1	1	9	176	3
IN	459	32	14	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10114	137	12	0	425
T	91	1827	59	1	48
P	7	34	850	22	17
M	0	0	7	177	8
IN	449	32	13	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10056	133	18	2	452
T	92	1839	62	0	37
P	9	51	846	11	24
M	0	0	11	187	5
IN	468	33	14	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10025	131	12	1	456
T	88	1847	72	0	49
P	8	35	885	9	14
M	0	0	14	179	10
IN	478	34	14	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10003	120	18	2	456
T	82	1854	53	2	56
P	10	45	918	13	11
M	0	0	16	170	6
IN	478	34	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	9985	129	18	1	440
T	87	1849	70	1	46
P	7	48	913	25	26
M	2	0	10	174	4
IN	466	33	14	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	9976	125	13	1	432
T	85	1861	65	0	48
P	10	36	943	13	23
M	5	0	10	183	6
IN	459	32	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	9992	120	14	0	409
T	95	1841	60	1	57
P	8	44	944	16	33
M	0	0	13	181	6
IN	456	32	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	9996	129	18	2	406
T	80	1864	49	0	44
P	8	52	944	18	22
M	2	0	3	188	8
IN	434	31	13	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229196	0.563038E+07	469	0.115848E+05
2	7456288	0.443237E+08	3579	0.353912E+05
3	20156166	0.154706E+09	4328	0.144542E+06
4	36746571	0.328075E+09	130328	0.812805E+06
5	37010653	0.483206E+09	283003	0.306645E+07
6	42157084	0.609528E+09	306823	0.405251E+07
7	59998431	0.573270E+09	325972	0.650099E+07
8	106032958	0.567465E+09	359125	0.306354E+07
9	153028330	0.609191E+09	505193	0.600475E+07
10	158878485	0.582847E+09	1911569	0.439611E+07
11	97391893	0.715449E+09	515303	0.482656E+07
12	115106667	0.792509E+09	846703	0.690212E+07
Average values				
	.695994E+08	0.455517E+09	.432700E+06	0.331811E+07

qtr	long items	long $	commit$	demval$
1	6739	0.347607E+08	0.285803E+08	0.675435E+08
2	6836	0.468328E+08	0.177593E+08	0.615278E+08
3	6919	0.632701E+08	0.295472E+08	0.585104E+08
4	7042	0.726194E+08	0.174388E+08	0.580336E+08
5	7104	0.746104E+08	0.291842E+08	0.616822E+08
6	7196	0.793823E+08	0.203364E+08	0.610628E+08
7	7320	0.875049E+08	0.252489E+08	0.596535E+08
8	7435	0.969753E+08	0.221074E+08	0.575687E+08
9	7479	0.101090E+09	0.325975E+08	0.612901E+08
10	7563	0.106519E+09	0.231780E+08	0.625208E+08
11	7649	0.111151E+09	0.282401E+08	0.632557E+08
12	7700	0.115227E+09	0.218407E+08	0.642338E+08
Average values				
	7248.5	0.824954E+08	0.246716E+08	0.614069E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 4
migsd= 1075
demsd= 1175

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10221	126	12	4	437
T	88	1826	62	0	53
P	4	39	748	15	16
M	2	0	7	177	2
IN	459	32	13	3	C

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10198	124	13	4	435
T	86	1818	70	0	49
P	4	25	774	9	30
M	0	0	8	185	6
IN	469	33	14	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10150	130	18	2	457
T	92	1804	54	1	49
P	7	51	785	22	14
M	3	0	8	185	5
IN	474	33	14	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10113	130	18	0	465
T	82	1814	68	0	54
P	2	41	801	16	19
M	0	2	8	195	8
IN	493	34	14	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10093	145	18	1	433
T	99	1796	73	0	53
P	8	41	824	13	23
M	2	0	12	193	7
IN	466	33	14	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10047	134	25	1	461
T	94	1801	67	1	52
P	8	37	862	14	20
M	0	0	10	194	6
IN	487	34	14	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10075	144	13	0	404
T	87	1806	68	0	45
P	5	40	881	25	27
M	2	0	4	204	3
IN	433	29	13	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10001	144	15	3	439
T	80	1828	59	0	52
P	8	37	885	19	30
M	1	0	12	211	8
IN	478	34	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	9975	143	13	2	435
T	77	1851	74	0	41
P	8	43	888	23	23
M	2	0	12	216	6
IN	456	32	13	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	9951	137	8	2	420
T	84	1869	59	0	57
P	8	51	902	12	27
M	2	0	10	223	9
IN	463	33	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	9911	145	17	0	435
T	83	1889	77	0	41
P	2	44	398	19	30
M	0	0	14	219	7
IN	463	33	14	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	9890	1[illegible]3	16	3	417
T	74	1910	66	0	61
P	12	43	931	16	18
M	0	0	9	225	7
IN	454	32	13	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468927	0.498455E+08	652	0.199509E+05
2	14275248	0.198239E+09	714	0.233083E+06
3	33269461	0.445949E+09	52895	0.156054E+07
4	51777698	0.768053E+09	211590	0.353465E+07
5	56661892	0.911740E+09	460370	0.868911E+07
6	52987706	0.802386E+09	325430	0.667259E+07
7	78627404	0.855336E+09	384758	0.758262E+07
8	110832682	0.773079E+09	899005	0.631812E+07
9	121246409	0.832270E+09	968237	0.777539E+07
10	121622408	0.924397E+09	489067	0.526781E+07
11	93386241	0.105642E+10	1288146	0.974768E+07
12	96684298	0.888598E+09	746775	0.857306E+07
Average values				
	.696200E+08	0.708859E+09	.485637E+06	0.549789E+07

•

qtr	long items	long $	commit$	demval$
1	6772	0.248360E+08	0.404105E+08	0.726718E+08
2	6842	0.398070E+08	0.197060E+08	0.751768E+08
3	6964	0.443995E+08	0.399799E+08	0.774171E+08
4	7062	0.520089E+08	0.215359E+08	0.770944E+08
5	7106	0.583719E+08	0.353331E+08	0.742661E+08
6	7208	0.653418E+08	0.215306E+08	0.742950E+08
7	7252	0.697237E+08	0.384764E+08	0.770744E+08
8	7368	0.749275E+06	0.286572E+08	0.808415E+08
9	7408	0.826027E+08	0.366687E+08	0.791643E+08
10	7487	0.797388E+08	0.243673E+08	0.802358E+08
11	7558	0.906126E+08	0.363526E+08	0.792118E+08
12	7632	0.103068E+09	0.274867E+08	0.765405E+08
Average values				
	7221.4	0.662090E+08	0.308754E+08	0.769991E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 5
migsd= 7099
demsd= 7395

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10145	145	9	3	498
T	80	1821	78	0	50
P	5	32	749	16	20
M	1	1	6	176	4
IN	517	36	14	4	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10144	126	17	1	460
T	85	1839	66	0	45
P	11	40	763	19	23
M	0	1	4	186	8
IN	484	34	14	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10128	150	23	2	421
T	66	1848	79	0	47
P	8	36	790	13	17
M	1	1	12	194	1
IN	439	31	13	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10037	140	16	2	447
T	78	1860	71	0	57
P	7	54	819	16	21
M	0	0	5	198	9
IN	482	34	14	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	9978	143	19	1	463
T	89	1874	76	1	48
P	10	39	840	12	24
M	2	0	7	205	5
IN	488	34	14	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	9977	155	3	1	431
T	96	1885	65	1	43
P	12	38	869	16	21
M	0	1	11	207	3
IN	449	32	13	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	9946	118	18	2	450
T	93	1912	60	1	45
P	6	40	872	18	25
M	1	1	6	212	8
IN	477	34	14	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	9902	141	16	2	462
T	87	1893	60	1	64
P	11	44	881	14	20
M	3	0	9	219	5
IN	498	34	14	4	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	9905	136	12	1	447
T	94	1902	65	1	50
P	9	33	898	15	25
M	1	0	4	225	10
IN	481	34	14	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	9899	119	8	1	463
T	82	1900	63	1	59
P	9	40	918	8	18
M	0	0	10	230	5
IN	492	34	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	9915	131	16	2	418
T	86	1237	59	0	51
P	10	32	934	14	23
M	1	0	8	229	5
IN	449	32	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	9860	115	26	1	459
T	97	1860	76	1	58
P	13	52	929	18	18
M	0	0	9	233	6
IN	489	34	14	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775917	0.370908E+08	7	0.211401E+04
2	55368053	0.175786E+09	22137	0.433833E+05
3	129969107	0.413738E+09	57694	0.105225E+07
4	198738672	0.708706E+09	908741	0.364694E+07
5	175822027	0.872055E+09	2350454	0.782779E+07
6	92868854	0.788427E+09	634979	0.657737E+07
7	104403928	0.724382E+09	945837	0.811856E+07
8	124379222	0.645802E+09	571175	0.466636E+07
9	135668691	0.727833E+09	2151764	0.714751E+07
10	114827452	0.707457E+09	411493	0.624074E+07
11	143684070	0.722732E+09	1048381	0.670080E+07
12	184845953	0.661374E+09	1437988	0.547387E+07
Average values				
	.122529E+09	0.598782E+09	.878387E+06	0.479147E+07

qtr	long items	long $	commit$	demval$
1	6781	0.460076E+08	0.355795E+08	0.647982E+08
2	6845	0.525109E+08	0.224785E+08	0.674631E+08
3	6866	0.586748E+08	0.338086E+08	0.688074E+08
4	7001	0.658047E+08	0.235361E+08	0.713635E+08
5	7076	0.697184E+08	0.298715E+08	0.682691E+08
6	7135	0.798532E+08	0.258822E+08	0.687910E+08
7	7258	0.844958E+08	0.329328E+08	0.722490E+08
8	7356	0.904294E+08	0.252421E+08	0.717971E+08
9	7441	0.928493E+08	0.327342E+08	0.751302E+08
10	7547	0.962199E+08	0.256531E+08	0.752493E+08
11	7570	0.971852E+08	0.340680E+08	0.795007E+08
12	7663	0.956744E+08	0.304946E+08	0.822326E+08
Average values				
	7211.6	0.774520E+08	0.293568E+08	0.721376E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 680.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2941506	0.231570E+08	34	0.472320E+04
2	10281801	0.102696E+09	126	0.539364E+05
3	25315488	0.260864E+09	16238	0.853786E+06
4	45722340	0.466057E+09	170454	0.180564E+07
5	59389036	0.655512E+09	278213	0.431682E+07
6	72564438	0.799490E+09	610450	0.650093E+07
7	71386926	0.755035E+09	424158	0.488357E+07
8	76812962	0.786331E+09	567684	0.669147E+07
9	82754353	0.642054E+09	663282	0.672663E+07
10	56034515	0.588355E+09	634780	0.402728E+07
11	70965650	0.679052E+09	464454	0.735787E+07
12	74418493	0.690386E+09	672409	0.472669E+07
Average values				
	.540490E+08	0.537413E+09	.375190E+06	0.399578E+07

qtr	long items	long $	commit$	demval$
1	6742	0.341256E+08	0.341950E+08	0.695378E+08
2	6811	0.413148E+08	0.202476E+08	0.694906E+08
3	6891	0.469273E+08	0.355776E+08	0.716015E+08
4	6949	0.506795E+08	0.229442E+08	0.742740E+08
5	7014	0.613702E+08	0.393918E+08	0.756709E+08
6	7083	0.677894E+08	0.232481E+08	0.779703E+08
7	7207	0.713839E+08	0.380548E+08	0.808892E+08
8	7250	0.727632E+08	0.227694E+08	0.832453E+08
9	7358	0.728339E+08	0.362773E+08	0.835426E+08
10	7388	0.896497E+08	0.297129E+08	0.840625E+08
11	7481	0.944072E+08	0.351136E+08	0.860210E+08
12	7585	0.102971E+09	0.312833E+08	0.851144E+08
Average values				
	7146.6	0.671846E+08	0.307346E+08	0.784517E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 680.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493086	0.293803E+08	70	0.193057E+05
2	11720918	0.144529E+09	823	0.290057E+05
3	26485553	0.338670E+09	61822	0.926832E+06
4	49727023	0.591257E+09	204972	0.235212E+07
5	75634927	0.732885E+09	356434	0.546909E+07
6	123527926	0.781906E+09	965611	0.681513E+07
7	173231673	0.874154E+09	446820	0.637772E+07
8	225281806	0.926060E+09	762416	0.578991E+07
9	218630239	0.104770E+10	4669540	0.100396E+08
10	69572283	0.676252E+09	592425	0.967862E+07
11	78548407	0.745621E+09	525041	0.671939E+07
12	95744583	0.775516E+09	690076	0.660595E+07
Average values				
	.958832E+08	0.655327E+09	.773004E+06	0.506856E+07

qtr	long items	long $	commit$	demval$
1	6771	0.349334E+08	0.397905E+08	0.717272E+08
2	6828	0.419490E+08	0.197558E+08	0.730873E+08
3	6882	0.595241E+08	0.350019E+08	0.697890E+08
4	6962	0.642627E+08	0.209420E+08	0.694410E+08
5	7043	0.738375E+08	0.347075E+08	0.687841E+08
6	7139	0.789235E+08	0.319068E+08	0.736257E+08
7	7224	0.848069E+08	0.320234E+08	0.742770E+08
8	7307	0.839716E+08	0.294109E+08	0.777732E+08
9	7407	0.920728E+08	0.307193E+09	0.754772E+08
10	7458	0.955441E+08	0.269994E+08	0.769444E+08
11	7513	0.925280E+08	0.289507E+08	0.783776E+08
12	7607	0.978746E+08	0.337059E+08	0.818653E+08
Average values				
	7178.4	0.750190E+08	0.303262E+08	0.742641E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 680.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229193	0.562970E+07	466	0.109090E+05
2	7456279	0.443229E+08	3570	0.345898E+05
3	20156106	0.154647E+09	4325	0.143837E+06
4	36745708	0.327804E+09	130328	0.812788E+06
5	37007493	0.481637E+09	282997	0.306126E+07
6	42154307	0.607632E+09	306786	0.402972E+07
7	59996261	0.570985E+09	325967	0.649759E+07
8	106030040	0.565670E+09	359106	0.304078E+07
9	153022998	0.607094E+09	505127	0.597736E+07
10	158870742	0.582108E+09	1911563	0.439300E+07
11	97382582	0.715105E+09	515255	0.481940E+07
12	115095353	0.792184E+09	846617	0.690041E+07
Average values				
	.695956E+08	0.454568E+09	.432676E+06	0.331014E+07

qtr	long items	long $	commit$	demval$
1	6739	0.347642E+08	0.295172E+08	0.675435E+08
2	6837	0.472185E+08	0.169562E+08	0.615278E+08
3	6920	0.640152E+08	0.297975E+08	0.585104E+08
4	7044	0.733531E+08	0.174958E+08	0.580336E+08
5	7106	0.753495E+08	0.293110E+08	0.616822E+08
6	7198	0.801420E+08	0.203942E+08	0.610628E+08
7	7320	0.883128E+08	0.253474E+08	0.596535E+08
8	7435	0.980819E+08	0.221945E+08	0.575687E+08
9	7480	0.102279E+09	0.327951E+08	0.612901E+08
10	7564	0.107775E+09	0.233439E+08	0.625208E+08
11	7650	0.112412E+09	0.284264E+08	0.632557E+08
12	7701	0.116628E+09	0.219348E+08	0.642338E+08
Average values				
	7249.5	0.833609E+08	0.247928E+08	0.614069E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 680.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468526	0.491814E+08	649	0.192751E+05
2	14274169	0.196455E+09	687	0.202392E+06
3	33268002	0.443537E+09	52906	0.158350E+07
4	51776608	0.766245E+09	211544	0.345847E+07
5	56660479	0.909696E+09	460394	0.873237E+07
6	52986777	0.801697E+09	325429	0.667085E+07
7	78626037	0.854568E+09	384723	0.758119E+07
8	110829435	0.771593E+09	898963	0.631728E+07
9	121231999	0.824277E+09	968193	0.777255E+07
10	121592520	0.907901E+09	488936	0.524809E+07
11	93954129	0.103724E+10	1287875	0.954339E+07
12	96669732	0.885297E+09	746599	0.854180E+07
Average values				
	.696115E+08	0.703974E+09	.485575E+06	0.547260E+07

qtr	long items	long $	commit$	demval$
1	6771	0.348375E+08	0.414742E+08	0.726718E+08
2	6842	0.399787E+08	0.189260E+08	0.751768E+08
3	6963	0.444903E+08	0.411948E+08	0.774171E+08
4	7061	0.534708E+08	0.216755E+08	0.770944E+08
5	7106	0.598706E+08	0.354916E+08	0.742661E+08
6	7207	0.668138E+08	0.215984E+08	0.742950E+08
7	7253	0.702201E+08	0.385359E+08	0.770744E+08
8	7369	0.765670E+08	0.289126E+08	0.808415E+08
9	7409	0.842994E+08	0.368358E+08	0.791643E+08
10	7488	0.814281E+08	0.245760E+08	0.802358E+08
11	7559	0.923138E+08	0.365140E+08	0.792118E+08
12	7633	0.104816E+09	0.276007E+08	0.765405E+08
Average values				
	7221.8	0.674246E+08	0.311113E+08	0.769991E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 680.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775694	0.367283E+08	4	0.143822E+04
2	55367771	0.175336E+09	22128	0.425782E+05
3	129968608	0.412888E+09	57678	0.102801E+07
4	198737953	0.707570E+09	908805	0.377641E+07
5	175819199	0.870072E+09	2350279	0.751974E+07
6	92863351	0.787103E+09	635176	0.697873E+07
7	104391072	0.721593E+09	945795	0.810875E+07
8	124365263	0.643301E+09	571073	0.466521E+07
9	135644804	0.724690E+09	2151504	0.710890E+07
10	114803887	0.704913E+09	411376	0.619738E+07
11	143636680	0.720249E+09	1047869	0.673425E+07
12	184799077	0.659142E+09	1437881	0.540151E+07
Average values				
	.122514E+09	0.596965E+09	.878297E+06	0.479691E+07

qtr	long items	long $	commit$	demval$
1	6780	0.464074E+08	0.366944E+08	0.647982E+08
2	6845	0.529548E+08	0.219140E+08	0.674631E+08
3	6866	0.595050E+08	0.347689E+08	0.688074E+08
4	7001	0.666647E+08	0.228020E+08	0.713635E+08
5	7076	0.709376E+08	0.307321E+08	0.682691E+08
6	7135	0.810865E+08	0.251974E+08	0.687910E+08
7	7258	0.857876E+08	0.338824E+08	0.722490E+08
8	7356	0.917574E+08	0.246486E+08	0.717971E+08
9	7440	0.941850E+08	0.336074E+08	0.751302E+08
10	7546	0.975585E+08	0.248581E+08	0.752493E+08
11	7570	0.984991E+08	0.350479E+08	0.795007E+08
12	7662	0.971422E+08	0.299091E+08	0.822326E+08
Average values				
	7211.3	0.785405E+08	0.295052E+08	0.721376E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 580.
Run number 1
migsd= 3905
damsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2942031	0.239700E+08	37	0.539899E+04
2	10283039	0.103940E+09	135	0.547415E+05
3	25318113	0.262752E+09	16269	0.874761E+06
4	49977394	0.494641E+09	24246	0.882055E+06
5	78372400	0.816086E+09	268945	0.304403E+07
6	99083964	0.115849E+10	373424	0.545921E+07
7	119150158	0.126644E+10	738993	0.703028E+07
8	118369093	0.130289E+10	775766	0.653267E+07
9	121434913	0.133768E+10	577076	0.728852E+07
10	145295152	0.136568E+10	692613	0.926055E+07
11	147241451	0.108064E+10	969164	0.616925E+07
12	111959371	0.124032E+10	507054	0.852032E+07
Average values				
	.857856E+08	0.871127E+09	.411977E+06	0.459348E+07

qtr	long items	long $	commit$	demval$
1	6743	0.342044E+08	0.350687E+08	0.655378E+08
2	6812	0.415778E+08	0.228816E+08	0.694906E+08
3	6891	0.472189E+08	0.368807E+08	0.716015E+08
4	6951	0.511395E+08	0.259376E+08	0.742740E+08
5	7014	0.626293E+08	0.418076E+08	0.756709E+08
6	7085	0.694239E+08	0.260334E+08	0.779703E+08
7	7209	0.732558E+08	0.395035E+08	0.808892E+08
8	7252	0.749899E+08	0.251683E+08	0.832453E+08
9	7357	0.761031E+08	0.371411E+08	0.835426E+08
10	7386	0.928366E+08	0.344248E+08	0.840625E+08
11	7487	0.982688E+08	0.364157E+08	0.860210E+08
12	7588	0.106077E+09	0.342710E+08	0.851144E+08
Average values				
	7147.9	0.689771E+08	0.329612E+08	0.784517E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 580.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493089	0.293810E+08	73	0.199815E+05
2	11722361	0.145336E+09	823	0.290168E+05
3	26489305	0.340766E+09	61E75	0.843654E+06
4	54890459	0.618204E+09	27591	0.171028E+07
5	94534494	0.890625E+09	383610	0.256767E+07
6	148733669	0.122441E+10	1038308	0.917608E+07
7	208495697	0.129195E+10	371318	0.652683E+07
8	268150095	0.132402E+10	765227	0.738989E+07
9	323393149	0.145691E+10	2474055	0.796799E+07
10	382028137	0.175910E+10	3338074	0.104456E+08
11	182211840	0.165592E+10	1055046	0.130268E+08
12	158198161	0.128514E+10	1096886	0.601916E+07
Average values				
	.155112E+09	0.100181E+10	.884391E+06	0.547692E+07

qtr	long items	long $	commit$	demval$
1	6770	0.349480E+08	0.412019E+08	0.717272E+08
2	6826	0.407875E+08	0.211198E+08	0.730873E+08
3	6881	0.586535E+08	0.373121E+08	0.697890E+08
4	6962	0.635401E+08	0.224998E+08	0.694410E+08
5	7044	0.731239E+08	0.376363E+08	0.687841E+08
6	7137	0.781631E+08	0.357689E+08	0.736257E+08
7	7224	0.840894E+08	0.340102E+08	0.742770E+08
8	7307	0.850477E+08	0.324405E+08	0.777732E+08
9	7405	0.936444E+08	0.330709E+08	0.751772E+08
10	7461	0.974263E+08	0.290392E+08	0.769444E+08
11	7520	0.946733E+08	0.310573E+08	0.783776E+08
12	7613	0.100875E+09	0.368243E+08	0.818653E+08
Average values				
	7179.2	0.754144E+08	0.326651E+08	0.742641E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 580.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229196	0.563038E+07	469	0.115848E+05
2	7456288	0.443237E+08	3579	0.353912E+05
3	20156166	0.154706E+09	4328	0.144542E+06
4	38651104	0.336631E+09	4356	0.351976E+06
5	51223163	0.560551E+09	410149	0.312932E+07
6	56044313	0.787810E+09	169227	0.347413E+07
7	88316153	0.979958E+09	357047	0.460466E+07
8	135705110	0.109107E+10	465280	0.747032E+07
9	177751377	0.866871E+09	425885	0.406044E+07
10	245943047	0.102090E+10	627836	0.552845E+07
11	307980151	0.107364E+10	810753	0.630771E+07
12	349150030	0.121941E+10	2916388	0.600511E+07
Average values				
	.123301E+09	0.678459E+09	.516275E+06	0.342697E+07

qtr	long items	long $	commit$	demval$
1	6739	0.348057E+08	0.293238E+08	0.675435E+08
2	6834	0.469832E+08	0.189507E+08	0.615278E+08
3	6920	0.635299E+08	0.320824E+08	0.585104E+08
4	7040	0.729981E+08	0.189065E+08	0.580336E+08
5	7102	0.751288E+08	0.313902E+08	0.616822E+08
6	7197	0.806533E+08	0.223888E+08	0.610628E+08
7	7321	0.894988E+08	0.267492E+08	0.596535E+08
8	7435	0.100491E+09	0.244669E+08	0.575687E+08
9	7479	0.105577E+09	0.367255E+08	0.612901E+08
10	7564	0.112194E+09	0.253008E+08	0.625208E+08
11	7652	0.117014E+09	0.311650E+08	0.632557E+08
12	7703	0.122064E+09	0.244376E+08	0.642338E+08
Average values				
	7248.8	0.850781E+08	0.268239E+08	0.614069E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 580.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468927	0.498455E+08	652	0.199509E+05
2	14275248	0.198239E+09	714	0.233083E+06
3	33269461	0.445949E+09	52895	0.156054E+07
4	56836791	0.816065E+09	36238	0.185891E+07
5	82698489	0.122366E+10	346618	0.411079E+07
6	99527222	0.162052E+10	520146	0.123045E+08
7	107759056	0.134466E+10	453022	0.670098E+07
8	149117137	0.144107E+10	465806	0.947089E+07
9	174540141	0.135856E+10	1477547	0.849610E+07
10	173497735	0.145401E+10	865252	0.839071E+07
11	181654939	0.150216E+10	387833	0.698581E+07
12	246921792	0.170877E+10	1484134	0.998945E+07
Average values				
	.110297E+09	0.109696E+10	.507571E+06	0.584348E+07

qtr	long items	long $	commit$	demval$
1	6772	0.349050E+08	0.437073E+08	0.726718E+08
2	6843	0.399392E+08	0.214693E+08	0.751768E+08
3	6965	0.446669E+08	0.433039E+08	0.774171E+08
4	7066	0.524228E+08	0.236600E+08	0.770944E+08
5	7108	0.593165E+08	0.377715E+08	0.742661E+08
6	7208	0.672776E+08	0.234205E+08	0.742950E+08
7	7255	0.710330E+08	0.412099E+08	0.770744E+08
8	7370	0.782235E+08	0.322639E+08	0.808415E+08
9	7407	0.868410E+08	0.394231E+08	0.791643E+08
10	7491	0.842964E+08	0.261010E+08	0.802358E+08
11	7565	0.962633E+08	0.391216E+08	0.792118E+08
12	7637	0.109788E+09	0.303520E+08	0.765405E+08
Average values				
	7223.9	0.687478E+08	0.334837E+08	0.769991E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 580.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775917	0.370908E+08	7	0.211401E+04
2	55368053	0.175786E+09	22137	0.433833E+05
3	129969107	0.413738E+09	57694	0.105225E+07
4	216269350	0.737800E+09	137254	0.242308E+07
5	290423628	0.109076E+10	1144410	0.441419E+07
6	327713978	0.144585E+10	943196	0.853470E+07
7	157043749	0.127895E+10	1074210	0.960966E+07
8	181719522	0.114952E+10	835607	0.611585E+07
9	178184658	0.113427E+10	1503007	0.846957E+07
10	218267214	0.118504E+10	1277533	0.654581E+07
11	221455987	0.131084E+10	1052968	0.680878E+07
12	271024813	0.136360E+10	1975039	0.995625E+07
Average values				
	.188101E+09	0.943603E+09	.835255E+06	0.533130E+07

qtr	long items	long $	commit$	demval$
1	6781	0.460429E+08	0.381262E+08	0.647982E+08
2	6845	0.525990E+08	0.250587E+08	0.674631E+08
3	6865	0.593570E+08	0.362334E+08	0.688074E+08
4	6998	0.666977E+08	0.255191E+08	0.713635E+08
5	7077	0.708662E+08	0.318412E+08	0.682691E+08
6	7133	0.814816E+08	0.283710E+08	0.687910E+08
7	7258	0.869343E+08	0.359268E+08	0.722490E+08
8	7359	0.933697E+08	0.273245E+08	0.717971E+08
9	7444	0.961403E+08	0.351469E+08	0.751302E+08
10	7550	0.999043E+08	0.274112E+08	0.752493E+08
11	7572	0.101064E+09	0.360746E+08	0.795007E+08
12	7666	0.100477E+09	0.336382E+08	0.822326E+08
Average values				
	7212.3	0.795778E+08	0.317227E+08	0.721376E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 680.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2941506	0.231570E+08	34	0.472320E+04
2	10281801	0.102696E+09	126	0.539364E+05
3	25315488	0.260864E+09	16238	0.853786E+06
4	49974685	0.492683E+09	24236	0.880672E+06
5	78369503	0.814095E+09	268941	0.304226E+07
6	99080394	0.115650E+10	373386	0.543752E+07
7	119147079	0.126533E+10	738960	0.701919E+07
8	118361920	0.130217E+10	775758	0.653445E+07
9	121411278	0.133617E+10	577009	0.728168E+07
10	145265234	0.136381E+10	692377	0.924371E+07
11	147202138	0.107839E+10	969055	0.616392E+07
12	111916575	0.123781E+10	510341	0.851288E+07
Average values				
	.857723E+08	0.869473E+09	.412205E+06	0.458573E+07

qtr	long items	long $	commit$	demval$
1	6743	0.341962E+08	0.360536E+08	0.695378E+08
2	6813	0.416456E+08	0.222200E+09	0.694906E+08
3	6892	0.474482E+06	0.379372E+08	0.716015E+08
4	6951	0.513921E+08	0.252331E+08	0.742740E+08
5	7014	0.629117E+08	0.430719E+08	0.756709E+08
6	7085	0.697870E+08	0.252884E+08	0.779703E+08
7	7209	0.736200E+08	0.404979E+08	0.808892E+08
8	7251	0.753943E+08	0.243646E+08	0.832453E+08
9	7357	0.766593E+08	0.381370E+08	0.835426E+08
10	7387	0.944581E+08	0.336666E+08	0.840625E+08
11	7488	0.100010E+09	0.373956E+08	0.860210E+08
12	7589	0.109096E+09	0.344986E+08	0.851144E+08
Average values				
	7148.3	0.697182E+08	0.331971E+08	0.784517E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 680.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493086	0.293803E+08	70	0.193057E+05
2	11720918	0.144529E+09	823	0.290057E+05
3	26485553	0.338670E+09	61822	0.926832E+06
4	54886871	0.616199E+09	27146	0.146124E+07
5	94530814	0.888568E+09	384105	0.284432E+07
6	148728136	0.122219E+10	1037524	0.873757E+07
7	208483210	0.129027E+10	371295	0.651387E+07
8	268138359	0.132346E+10	765169	0.738491E+07
9	323380446	0.145656E+10	2474004	0.796780E+07
10	382007049	0.175868E+10	3337948	0.104413E+08
11	182194182	0.165570E+10	1054981	0.130265E+08
12	158175588	0.128405E+10	1096609	0.601605E+07
Average values				
	.155102E+09	0.100069E+10	.884291E+06	0.544738E+07

qtr	long items	long $	commit$	demval$
1	6770	0.349724E+08	0.424326E+03	0.717272E+06
2	6828	0.420602E+08	0.214523E+08	0.730873E+08
3	6883	0.603766E+08	0.376387E+08	0.697890E+08
4	6965	0.653007E+08	0.228008E+08	0.694410E+08
5	7046	0.756196E+08	0.378538E+08	0.687841E+08
6	7139	0.810773E+08	0.361563E+08	0.736257E+08
7	7226	0.870127E+08	0.340477E+08	0.742770E+08
8	7303	0.867974E+08	0.326824E+08	0.777732E+08
9	7408	0.954371E+08	0.331660E+08	0.754772E+08
10	7462	0.992431E+08	0.291364E+08	0.769444E+08
11	7521	0.965260E+08	0.311436E+08	0.783776E+08
12	7613	0.102728E+09	0.370288E+08	0.818653E+08
Average values				
	7180.8	0.772626E+08	0.329616E+08	0.742641E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 680.
Run number 3
migsd= 5745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229193	0.562970E+07	466	0.109090E+05
2	7456279	0.443229E+08	3570	0.345898E+05
3	20156106	0.154647E+09	4325	0.143837E+06
4	38650913	0.336362E+09	4358	0.351960E+06
5	51221707	0.558986E+09	410143	0.312413E+07
6	56040156	0.785878E+09	169213	0.345036E+07
7	86311055	0.977482E+09	357042	0.460126E+07
8	135700254	0.108927E+10	465234	0.744752E+07
9	177748032	0.864408E+09	425870	0.405794E+07
10	245930780	0.101815E+10	627767	0.550190E+07
11	307964913	0.107274E+10	810694	0.630282E+07
12	349136405	0.121863E+10	2916329	0.599984E+07
Average values				
	.123295E+09	0.677209E+09	.516251E+06	0.341892E+07

qtr	long items	long $	commit$	demval$
1	6739	0.348092E+08	0.302733E+08	0.675435E+08
2	6835	0.473689E+08	0.181560E+08	0.615278E+08
3	6921	0.642779E+08	0.323951E+08	0.585104E+08
4	7042	0.737368E+08	0.189812E+08	0.580336E+08
5	7104	0.758728E+08	0.315449E+08	0.616822E+08
6	7199	0.814211E+08	0.224702E+08	0.610628E+08
7	7321	0.903144E+08	0.268570E+08	0.596535E+08
8	7435	0.101635E+09	0.246097E+08	0.575687E+08
9	7480	0.106836E+09	0.369793E+08	0.612901E+08
10	7565	0.113542E+09	0.255214E+08	0.625208E+08
11	7653	0.118372E+09	0.313669E+08	0.632557E+08
12	7704	0.123589E+09	0.245652E+08	0.642338E+08
Average values				
	7249.8	0.859812E+08	0.269767E+08	0.614069E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 680.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468526	0.491814E+08	649	0.192751E+05
2	14274169	0.196455E+09	687	0.202392E+06
3	33268002	0.443537E+09	52906	0.158350E+07
4	56835701	0.814258E+09	36192	0.178273E+07
5	82696851	0.122122E+10	346657	0.417881E+07
6	99525358	0.161783E+10	520131	0.122797E+08
7	107757781	0.134351E+10	453017	0.669639E+07
8	149114722	0.143994E+10	465804	0.947086E+07
9	174526832	0.135067E+10	1477536	0.849218E+07
10	173468046	0.143810E+10	865138	0.836651E+07
11	181616525	0.148167E+10	387626	0.680135E+07
12	246896312	0.170236E+10	1483872	0.994641E+07
Average values				
	.110287E+09	0.109156E+10	.507518E+06	0.581835E+07

qtr	long items	long $	commit$	demval$
1	6771	0.349065E+08	0.448751E+08	0.726718E+08
2	6843	0.401160E+08	0.207015E+08	0.751768E+08
3	6964	0.447514E+08	0.446118E+08	0.774171E+08
4	7065	0.538909E+08	0.238326E+08	0.770944E+08
5	7107	0.608411E+08	0.379886E+08	0.742661E+08
6	7208	0.688078E+08	0.235222E+08	0.742950E+08
7	7255	0.725836E+08	0.413104E+08	0.770744E+08
8	7371	0.798527E+08	0.325736E+08	0.808415E+08
9	7408	0.886389E+08	0.396593E+08	0.791643E+08
10	7492	0.860844E+08	0.263592E+08	0.802358E+08
11	7566	0.980754E+08	0.393070E+08	0.792118E+08
12	7638	0.111661E+09	0.305355E+08	0.765405E+08
Average values				
	7224.0	0.700175E+08	0.337731E+08	0.769991E+08

Model output

No information lag
Variable lead time
Implied shortage factor= 680.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775694	0.367283E+08	4	0.143822E+04
2	55367771	0.175336E+09	22128	0.425782E+05
3	129968608	0.412888E+09	57678	0.102801E+07
4	216268703	0.736698E+09	137318	0.255255E+07
5	290420810	0.108871E+10	1144238	0.411107E+07
6	327710730	0.144409E+10	943393	0.893114E+07
7	157035965	0.127681E+10	1074204	0.960891E+07
8	181704468	0.114610E+10	835579	0.610597E+07
9	178164218	0.113084E+10	1502862	0.844213E+07
10	218240171	0.118036E+10	1277428	0.650391E+07
11	221421178	0.130685E+10	1052783	0.683082E+07
12	270995499	0.136080E+10	1974802	0.988687E+07
Average values				
	.1880P9E+09	0.941351E+09	.835201E+06	0.533712E+07

qtr	long items	long $	commit$	demval$
1	6780	0.464505E+08	0.392750E+08	0.647982E+08
2	6845	0.530435E+08	0.245620E+08	0.674631E+08
3	6865	0.602173E+08	0.372151E+08	0.688074E+08
4	6998	0.675898E+08	0.248002E+08	0.713635E+08
5	7077	0.721182E+08	0.327090E+08	0.682691E+08
6	7133	0.827446E+08	0.277422E+08	0.687910E+08
7	7258	0.882664E+08	0.369179E+08	0.722490E+08
8	7360	0.947514E+08	0.267574E+08	0.717971E+08
9	7444	0.975298E+08	0.360407E+08	0.751302E+08
10	7549	0.101297E+09	0.266316E+08	0.752493E+08
11	7571	0.102428E+09	0.370977E+08	0.795007E+08
12	7665	0.102014E+09	0.331240E+08	0.822326E+08
Average values				
	7212.1	0.807042E+08	0.319061E+08	0.721376E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 580.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2942031	0.239700E+08	37	0.539899E+04
2	10283039	0.103940E+09	135	0.547416E+05
3	25318113	0.262752E+09	16269	0.874761E+06
4	46215291	0.468403E+09	183096	0.180906E+07
5	66436158	0.726657E+09	411948	0.678078E+07
6	92955537	0.103762E+10	2396798	0.128943E+08
7	121294268	0.126042E+10	953862	0.173472E+08
8	141720352	0.126927E+10	1152005	0.170565E+08
9	159240489	0.120581E+10	1752001	0.198207E+08
10	159159202	0.125014E+10	3310046	0.160594E+08
11	161097569	0.131758E+10	1476424	0.218959E+08
12	168665806	0.133560E+10	2099821	0.169584E+08
Average values				
	.962773E+08	0.855180E+09	.114604E+07	0.109631E+08

qtr	long items	long $	commit$	demval$
1	6744	0.343830E+08	0.277703E+08	0.695378E+08
2	6814	0.414708E+08	0.160320E+08	0.694906E+08
3	6894	0.475047E+08	0.362065E+08	0.716015E+08
4	6953	0.513229E+08	0.221858E+08	0.742740E+08
5	7015	0.608297E+08	0.356356E+08	0.756709E+08
6	7082	0.661059E+08	0.244545E+08	0.779703E+08
7	7205	0.700844E+08	0.370309E+08	0.808892E+08
8	7248	0.713581E+08	0.255339E+08	0.832453E+08
9	7345	0.704637E+08	0.358209E+08	0.835426E+08
10	7378	0.866739E+08	0.235046E+08	0.840625E+08
11	7475	0.907281E+08	0.385558E+08	0.860210E+08
12	7578	0.981222E+08	0.256765E+08	0.851144E+08
Average values				
	7144.6	0.657540E+08	0.290339E+08	0.784517E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 580.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493089	0.293810E+08	73	0.199815E+05
2	11722361	0.145336E+09	823	0.290168E+05
3	26489305	0.340766E+09	61675	0.643654E+06
4	53032177	0.595417E+09	250763	0.279996E+07
5	90228637	0.820745E+09	1061179	0.842824E+07
6	147936060	0.112525E+10	1786068	0.196853E+08
7	214601037	0.145280E+10	1448547	0.199790E+08
8	268181597	0.158029E+10	949831	0.145867E+08
9	324150458	0.174635E+10	14650493	0.288530E+08
10	389101457	0.187926E+10	2419111	0.327047E+08
11	335905918	0.188212E+10	3914334	0.291929E+08
12	253876260	0.170352E+10	2459205	0.210987E+08
Average values				
	.176477E+09	0.110844E+10	.241684E+07	0.148518E+08

qtr	long items	long $	commit$	demval$
1	6772	0.352102E+08	0.304942E+08	0.717272E+08
2	6827	0.410021E+08	0.173993E+08	0.730873E+08
3	6880	0.587932E+08	0.301373E+08	0.697890E+08
4	6958	0.635534E+08	0.210392E+08	0.694410E+08
5	7039	0.727473E+08	0.306522E+08	0.687841E+08
6	7135	0.775228E+08	0.307328E+08	0.736257E+08
7	7220	0.835436E+08	0.349892E+08	0.742770E+08
8	7302	0.841368E+08	0.259366E+08	0.777732E+08
9	7402	0.931261E+08	0.360687E+08	0.754772E+08
10	7458	0.966746E+08	0.270753E+08	0.769444E+08
11	7510	0.933952E+08	0.326415E+08	0.783776E+08
12	7606	0.989276E+08	0.261899E+08	0.818653E+08
Average values				
	7175.8	0.748861E+08	0.286130E+08	0.742641E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 580.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229196	0.563038E+07	469	0.115848E+05
2	7456288	0.443237E+08	3579	0.353912E+05
3	20156166	0.154706E+09	4328	0.144542E+06
4	37665669	0.329721E+09	570139	0.170165E+07
5	51987581	0.545809E+09	460475	0.375864E+07
6	57557259	0.763818E+09	598424	0.103213E+08
7	88765909	0.947198E+09	633816	0.169874E+08
8	134796708	0.114533E+10	1195215	0.116319E+08
9	182442152	0.121316E+10	1603023	0.187932E+08
10	239713354	0.110216E+10	9653656	0.167220E+08
11	297557111	0.117906E+10	2201751	0.168560E+08
12	343933858	0.131561E+10	1698239	0.168514E+08
Average values				
	.121938E+09	0.728876E+09	.155193E+07	0.948459E+07

qtr	long items	long $	commit$	demval$
1	6740	0.350517E+08	0.257024E+08	0.675435E+08
2	6834	0.471886E+08	0.165720E+08	0.615278E+08
3	6919	0.642516E+08	0.236302E+08	0.585104E+08
4	7045	0.735757E+08	0.176585E+08	0.580336E+08
5	7105	0.757113E+08	0.276405E+08	0.616822E+08
6	7195	0.801029E+08	0.211765E+08	0.610628E+08
7	7318	0.887754E+08	0.249895E+08	0.596535E+08
8	7432	0.976315E+08	0.216408E+08	0.575687E+08
9	7472	0.101316E+09	0.281134E+08	0.612901E+08
10	7556	0.106502E+09	0.243440E+08	0.625208E+08
11	7643	0.111397E+09	0.292585E+08	0.632557E+08
12	7697	0.115424E+09	0.213147E+08	0.642338E+08
Average values				
	7246.3	0.830773E+08	0.235034E+08	0.614069E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 580.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468927	0.498455E+08	652	0.199509E+05
2	14275248	0.198239E+09	714	0.233083E+06
3	33269461	0.445949E+09	52895	0.156054E+07
4	54905350	0.770390E+09	678605	0.374979E+07
5	77168594	0.104341E+10	951505	0.173288E+08
6	92753127	0.132842E+10	957623	0.187711E+08
7	118091935	0.162170E+10	894362	0.209070E+08
8	146595984	0.162567E+10	1509459	0.245741E+08
9	155287640	0.167391E+10	1987206	0.225735E+08
10	179644817	0.159998E+10	2084530	0.176064E+08
11	204757323	0.177544E+10	4480711	0.262410E+08
12	207169339	0.161732E+10	1669692	0.281149E+08
Average values				
	.107281E+09	0.114586E+10	.127233E+07	0.151400E+08

qtr	long items	long $	commit$	demval$
1	6772	0.350411E+08	0.297824E+08	0.726718E+08
2	6841	0.400672E+08	0.173557E+08	0.751768E+08
3	6962	0.447825E+08	0.366248E+08	0.774171E+08
4	7061	0.523625E+08	0.209844E+08	0.770944E+08
5	7100	0.581864E+08	0.346724E+08	0.742661E+08
6	7203	0.653577E+08	0.256740E+08	0.742950E+08
7	7251	0.680109E+08	0.364270E+08	0.770744E+08
8	7366	0.745585E+08	0.259241E+08	0.808415E+08
9	7407	0.825981E+08	0.375058E+08	0.791643E+08
10	7485	0.801343E+08	0.273855E+08	0.802358E+08
11	7552	0.918083E+08	0.360398E+08	0.792118E+08
12	7626	0.102589E+09	0.267409E+08	0.765405E+08
Average values				
	7218.8	0.662914E+08	0.295931E+08	0.769991E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 580.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775917	0.370908E+08	7	0.211401E+04
2	55368053	0.175786E+09	22137	0.433833E+05
3	129969107	0.413738E+09	57694	0.105225E+07
4	199813219	0.710543E+09	1026414	0.371055E+07
5	247131930	0.100401E+10	11814046	0.171092E+08
6	324989191	0.130873E+10	2378931	0.204859E+08
7	188993308	0.149164E+10	1724248	0.208741E+08
8	228233699	0.155065E+10	1819218	0.180163E+08
9	215320863	0.142914E+10	3492435	0.217158E+08
10	218894257	0.139861E+10	4022159	0.212577E+08
11	240068396	0.130242E+10	2757822	0.208333E+08
12	267352219	0.132537E+10	2677705	0.196326E+08
Average values				
	.193826E+09	0.101231E+10	.264940E+07	0.137278E+08

qtr	long items	long $	commit$	demval$
1	6783	0.460405E+08	0.262915E+08	0.647982E+08
2	6847	0.525628E+08	0.172748E+08	0.674631E+08
3	6868	0.580520E+08	0.307612E+08	0.688074E+08
4	7000	0.652440E+08	0.266011E+08	0.713635E+08
5	7075	0.692771E+08	0.326182E+08	0.682691E+08
6	7134	0.790504E+08	0.255480E+08	0.687910E+08
7	7257	0.842080E+08	0.323151E+08	0.722490E+08
8	7358	0.910161E+08	0.238614E+08	0.717971E+08
9	7446	0.935150E+08	0.314990E+08	0.751302E+08
10	7551	0.971284E+08	0.311160E+08	0.752493E+08
11	7573	0.981904E+08	0.307257E+08	0.795007E+08
12	7668	0.972445E+08	0.315296E+08	0.822326E+08
Average values				
	7213.3	0.776274E+08	0.283451E+08	0.721376E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 680.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2941506	0.231570E+08	34	0.472320E+04
2	10281801	0.102696E+09	126	0.539364E+05
3	25315488	0.260864E+09	16238	0.853786E+06
4	46212526	0.466444E+09	183086	0.180767E+07
5	66433243	0.724666E+09	411925	0.674815E+07
6	92952560	0.103563E+10	2396751	0.128609E+08
7	121291450	0.125850E+10	953791	0.173158E+08
8	141713166	0.126832E+10	1151987	0.170488E+08
9	159216985	0.120433E+10	1751941	0.198107E+08
10	159129851	0.124828E+10	3309773	0.160471E+08
11	161063107	0.131547E+10	1476081	0.218557E+08
12	168632228	0.133389E+10	2099288	0.169434E+08
Average values				
	.962653E+08	0.853519E+09	.114592E+07	0.109459E+08

qtr	long items	long $	commit$	demval$
1	6743	0.343749E+08	0.286347E+08	0.695378E+08
2	6814	0.415422E+08	0.152435E+08	0.694906E+08
3	6894	0.477325E+08	0.372541E+08	0.716015E+08
4	6953	0.515697E+08	0.214169E+08	0.742740E+08
5	7015	0.610651E+08	0.366207E+08	0.756709E+08
6	7082	0.663680E+08	0.238589E+08	0.779703E+08
7	7205	0.703485E+08	0.380119E+08	0.808892E+08
8	7248	0.716423E+08	0.247159E+08	0.832453E+08
9	7349	0.708246E+08	0.367554E+08	0.835426E+08
10	7379	0.880965E+08	0.226396E+08	0.840625E+08
11	7476	0.922811E+08	0.396051E+08	0.860210E+08
12	7579	0.100965E+09	0.257333E+08	0.851144E+08
Average values				
	7144.8	0.664009E+08	0.292075E+08	0.784517E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 680.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493066	0.293803E+08	70	0.193057E+05
2	11720918	0.144529E+09	823	0.290057E+05
3	26485553	0.338670E+09	61822	0.926832E+06
4	53028589	0.593411E+09	250318	0.255092E+07
5	90224866	0.818533E+09	1061894	0.912589E+07
6	147933525	0.112800E+10	1785747	0.191506E+08
7	214616232	0.149378E+10	1447678	0.195118E+08
8	268203650	0.163194E+10	949815	0.145783E+08
9	324171679	0.180122E+10	14650211	0.288499E+08
10	389107314	0.191795E+10	2419250	0.332912E+08
11	335889529	0.188191E+10	3914194	0.291896E+08
12	253853691	0.170238E+10	2458896	0.210932E+08
Average values				
	.176477E+09	0.112347E+10	.241673E+07	0.148597E+08

qtr	long items	long $	commit$	demval$
1	6771	0.352294E+08	0.313847E+08	0.717272E+08
2	6827	0.422738E+08	0.169552E+08	0.730873E+08
3	6880	0.605009E+08	0.311117E+08	0.697890E+08
4	6959	0.652973E+08	0.203026E+08	0.694410E+08
5	7039	0.752167E+08	0.320866E+08	0.687841E+08
6	7135	0.803959E+08	0.303848E+08	0.736257E+08
7	7220	0.864260E+08	0.354826E+08	0.742770E+08
8	7303	0.858294E+08	0.260523E+08	0.777732E+08
9	7402	0.948217E+08	0.363653E+08	0.754772E+08
10	7458	0.983915E+08	0.269984E+08	0.769444E+08
11	7510	0.951125E+08	0.328524E+08	0.783776E+08
12	7606	0.100631E+09	0.260591E+08	0.818653E+08
Average values				
	7175.8	0.766771E+08	0.288363E+08	0.742641E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 680.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229193	0.562970E+07	466	0.109090E+05
2	7456279	0.443229E+08	3570	0.345898E+05
3	20156106	0.154647E+09	4325	0.143837E+06
4	37665478	0.329452E+09	570139	0.170163E+07
5	51986605	0.544246E+09	460469	0.375345E+07
6	57555981	0.761876E+09	598411	0.102986E+08
7	88764021	0.944675E+09	633810	0.169833E+08
8	134795151	0.114351E+10	1195199	0.116063E+08
9	182437757	0.121075E+10	1602952	0.187660E+08
10	239701444	0.110108E+10	9653502	0.166652E+08
11	297542943	0.117775E+10	2201696	0.168159E+08
12	343920056	0.131493E+10	1698113	0.168478E+08
Average values				
	.121934E+09	0.727740E+09	.155189E+07	0.946896E+07

qtr	long items	long $	commit$	demval$
1	6739	0.350501E+08	0.265735E+08	0.675435E+08
2	6834	0.475693E+08	0.157843E+08	0.615278E+08
3	6919	0.649916E+08	0.236475E+08	0.585104E+08
4	7045	0.743046E+08	0.178385E+08	0.580336E+08
5	7105	0.764458E+08	0.277649E+08	0.616822E+08
6	7195	0.808412E+08	0.211764E+08	0.610628E+08
7	7317	0.895619E+08	0.250318E+08	0.596535E+08
8	7431	0.986723E+08	0.217814E+08	0.575687E+08
9	7472	0.102437E+09	0.281785E+08	0.612901E+08
10	7556	0.107672E+09	0.245100E+08	0.625208E+08
11	7643	0.112574E+09	0.293677E+08	0.632557E+08
12	7697	0.116701E+09	0.214293E+08	0.642338E+08
Average values				
	7246.1	0.839017E+08	0.235903E+08	0.614069E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 680.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468526	0.431814E+08	649	0.192751E+05
2	14274169	0.196455E+09	687	0.202392E+06
3	33268002	0.443537E+09	52906	0.158350E+07
4	54904260	0.768582E+09	678559	0.367361E+07
5	77167139	0.104109E+10	951476	0.172846E+08
6	92751840	0.132658E+10	957632	0.187851E+08
7	118080833	0.162086E+10	894329	0.209058E+08
8	146595154	0.162549E+10	1509418	0.245737E+08
9	155281455	0.167125E+10	1987152	0.225650E+08
10	179623872	0.158935E+10	2084507	0.176060E+08
11	204731391	0.176104E+10	4480523	0.261553E+08
12	207141797	0.160314E+10	1669458	0.279529E+08
Average values				
	.107274E+09	0.114138E+10	.127227E+07	0.151089E+08

qtr	long items	long $	commit$	demval$
1	6771	0.350427E+08	0.306775E+08	0.726718E+08
2	6841	0.401862E+08	0.164886E+08	0.751768E+08
3	6961	0.448737E+08	0.376343E+08	0.774171E+08
4	7060	0.537613E+08	0.211746E+08	0.770944E+08
5	7100	0.596056E+08	0.347921E+08	0.742661E+08
6	7204	0.668122E+08	0.258637E+08	0.742950E+08
7	7252	0.694897E+08	0.365066E+08	0.770744E+08
8	7367	0.761103E+08	0.260745E+08	0.808415E+08
9	7408	0.842772E+08	0.375599E+08	0.791643E+08
10	7486	0.818164E+08	0.276312E+08	0.802358E+08
11	7553	0.935024E+08	0.362073E+08	0.792118E+08
12	7627	0.104299E+09	0.269134E+08	0.765405E+08
Average values				
	7219.2	0.674814E+08	0.297936E+08	0.769991E+08

Model output

One quarter information lag
Constant lead time
Implied shortage factor= 680.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775694	0.367283E+08	4	0.143822E+04
2	55367771	0.175336E+09	22128	0.425782E+05
3	129968608	0.412888E+09	57678	0.102801E+07
4	199812544	0.709407E+09	1026478	0.384001E+07
5	247129246	0.100196E+10	11813868	0.167962E+08
6	324986217	0.130696E+10	2379122	0.208724E+08
7	188980321	0.148926E+10	1724229	0.208525E+08
8	228222136	0.154762E+10	1818911	0.174905E+08
9	215265647	0.137426E+10	3492539	0.222942E+08
10	218838919	0.134775E+10	4021381	0.203931E+08
11	240042988	0.130054E+10	2757703	0.209069E+08
12	267324449	0.132232E+10	2677200	0.195428E+08
Average values				
	.193810E+09	0.100209E+10	.264927E+07	0.136717E+08

qtr	long items	long $	commit$	demval$
1	6782	0.464785E+08	0.273338E+08	0.647982E+08
2	6847	0.530449E+08	0.165022E+08	0.674631E+08
3	6868	0.588152E+08	0.317529E+08	0.688074E+08
4	7000	0.660368E+08	0.267238E+08	0.713635E+08
5	7075	0.704290E+08	0.325444E+08	0.682691E+08
6	7134	0.802120E+08	0.250536E+08	0.687910E+08
7	7257	0.854282E+08	0.329677E+08	0.722490E+08
8	7359	0.922820E+08	0.235296E+08	0.717971E+08
9	7447	0.947875E+08	0.321368E+08	0.751302E+08
10	7552	0.984025E+08	0.306192E+08	0.752493E+08
11	7573	0.994385E+08	0.314351E+08	0.795007E+08
12	7668	0.986466E+08	0.310404E+08	0.822326E+08
Average values				
	7213.5	0.786668E+08	0.284700E+08	0.721376E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 580.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2942031	0.239700E+08	37	0.539899E+04
2	10283039	0.103940E+09	135	0.547416E+05
3	25318113	0.262752E+09	16269	0.874761E+06
4	49977394	0.494641E+09	24246	0.882055E+06
5	80999585	0.825370E+09	245923	0.275984E+07
6	107461972	0.121101E+10	574872	0.501046E+07
7	138534177	0.150086E+10	3009999	0.141091E+08
8	178902929	0.190501E+10	1077061	0.227673E+08
9	197036729	0.191791E+10	2019357	0.196628E+08
10	224711529	0.181425E+10	869182	0.188502E+08
11	263236310	0.185362E+10	2004326	0.252390E+08
12	281855629	0.215383E+10	4529509	0.188214E+08
Average values				
	.130105E+09	0.117226E+10	.119758E+07	0.107531E+08

qtr	long items	long $	commit$	demval$
1	6744	0.344588E+08	0.282950E+08	0.695378E+08
2	6814	0.417557E+08	0.167344E+08	0.694906E+08
3	6893	0.479777E+08	0.386866E+08	0.716015E+08
4	6956	0.520306E+08	0.241759E+08	0.742740E+08
5	7016	0.619999E+08	0.376416E+08	0.756709E+08
6	7084	0.671492E+08	0.233758E+08	0.779703E+08
7	7203	0.712808E+08	0.411483E+08	0.808892E+08
8	7244	0.725832E+08	0.259379E+08	0.832453E+08
9	7347	0.725090E+08	0.376460E+08	0.835426E+08
10	7376	0.897991E+08	0.248810E+08	0.840625E+08
11	7474	0.943616E+08	0.393437E+08	0.860210E+08
12	7575	0.102215E+09	0.268031E+08	0.851144E+08
Average values				
	7143.8	0.673434E+08	0.303891E+08	0.784517E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 580.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493089	0.293810E+08	73	0.199815E+05
2	11722361	0.145336E+09	823	0.290168E+05
3	26489305	0.340766E+09	61675	0.843654E+06
4	54890459	0.618204E+09	27591	0.171028E+07
5	98719857	0.901477E+09	438729	0.258893E+07
6	167540195	0.129129E+10	1589547	0.760679E+07
7	236716913	0.166140E+10	1665610	0.232946E+08
8	303762347	0.184341E+10	1135848	0.175943E+08
9	375536387	0.219335E+10	3186040	0.216235E+08
10	439026773	0.250475E+10	2264692	0.195333E+08
11	519456038	0.262391E+10	13598307	0.320274E+08
12	349264429	0.281088E+10	4396887	0.428193E+08
Average values				
	.215468E+09	0.141368E+10	.236382E+07	0.141409E+08

qtr	long items	long $	commit$	demval$
1	6771	0.352492E+08	0.311400E+08	0.717272E+08
2	6827	0.411100E+08	0.184588E+08	0.730873E+08
3	6880	0.596206E+08	0.316680E+08	0.697890E+08
4	6960	0.645604E+08	0.224205E+08	0.694410E+08
5	7043	0.744887E+08	0.313835E+08	0.687841E+08
6	7136	0.796199E+08	0.314624E+08	0.736257E+08
7	7221	0.856941E+08	0.403719E+08	0.742770E+08
8	7302	0.869372E+08	0.300523E+08	0.777732E+08
9	7400	0.962140E+08	0.357240E+08	0.754772E+08
10	7455	0.100099E+09	0.279072E+08	0.769444E+08
11	7513	0.969957E+08	0.317936E+08	0.783776E+08
12	7608	0.103544E+09	0.314651E+08	0.818653E+08
Average values				
	7176.3	0.770111E+08	0.303206E+08	0.742641E+08

Model output

Cne quarter information lag
Variable lead time
Implied shortage factor= 580.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229196	0.563038E+07	469	0.115848E+05
2	7456288	0.443237E+08	3579	0.353912E+05
3	20156166	0.154706E+09	4328	0.144542E+06
4	38651104	0.336631E+09	4356	0.351976E+06
5	56559025	0.575241E+09	819093	0.330167E+07
6	74392895	0.859265E+09	819643	0.610936E+07
7	99590088	0.111546E+10	628347	0.101216E+08
8	154536498	0.132692E+10	553660	0.119291E+08
9	214918768	0.155714E+10	1431563	0.223205E+08
10	284054912	0.164176E+10	1313336	0.135120E+08
11	348697757	0.172607E+10	1482675	0.182275E+08
12	410184559	0.186035E+10	5817486	0.202243E+08
Average values				
	.142536E+09	0.933625E+09	.107321E+07	0.885746E+07

qtr	long items	long $	commit$	demval$
1	6740	0.350967E+08	0.258003E+08	0.675435E+08
2	6832	0.473382E+08	0.172911E+08	0.615278E+08
3	6918	0.645119E+08	0.244643E+08	0.585104E+08
4	7042	0.739563E+08	0.179547E+08	0.580336E+08
5	7104	0.762256E+08	0.287625E+08	0.616822E+08
6	7196	0.812106E+08	0.236910E+08	0.610628E+08
7	7318	0.906077E+08	0.260040E+08	0.596535E+08
8	7430	0.100914E+09	0.227773E+08	0.575687E+08
9	7471	0.105087E+09	0.256878E+08	0.612901E+08
10	7555	0.110947E+09	0.271735E+08	0.625208E+08
11	7643	0.115921E+09	0.294017E+08	0.632557E+08
12	7696	0.121014E+09	0.284448E+08	0.642338E+08
Average values				
	7245.4	0.852359E+08	0.247877E+08	0.614069E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 580.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468927	0.498455E+08	652	0.199509E+05
2	14275248	0.198239E+09	714	0.233083E+06
3	33269461	0.445949E+09	52895	0.156054E+07
4	56836791	0.816065E+09	36238	0.185891E+07
5	87618731	0.124050E+10	934065	0.405664E+07
6	122445686	0.170861E+10	761908	0.118962E+08
7	151623226	0.191464E+10	1652674	0.301245E+08
8	196176861	0.217129E+10	877680	0.188007E+08
9	226773810	0.229466E+10	1849247	0.323989E+08
10	220143208	0.240305E+10	1804301	0.257712E+08
11	249657728	0.249396E+10	2343026	0.253356E+08
12	324641475	0.269114E+10	1559675	0.176543E+08
Average values				
	.140578E+09	0.153566E+10	.989423E+06	0.141425E+08

qtr	long items	long $	commit$	demval$
1	6773	0.351179E+08	0.308054E+08	0.726718E+08
2	6843	0.401997E+08	0.184308E+08	0.751768E+08
3	6963	0.450124E+08	0.387740E+08	0.774171E+08
4	7062	0.526948E+08	0.225269E+08	0.770944E+08
5	7100	0.588023E+08	0.358033E+08	0.742661E+08
6	7202	0.670182E+08	0.268333E+08	0.742950E+08
7	7249	0.698618E+08	0.383143E+08	0.770744E+08
8	7366	0.772661E+08	0.296424E+08	0.808415E+08
9	7401	0.856242E+08	0.396160E+08	0.791643E+08
10	7484	0.834979E+08	0.307383E+08	0.802358E+08
11	7558	0.963591E+08	0.365594E+08	0.792118E+08
12	7628	0.107795E+09	0.307301E+08	0.765405E+08
Average values				
	7219.1	0.682708E+08	0.315345E+08	0.769991E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 580.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775917	0.370908E+08	7	0.211401E+04
2	55368053	0.175786E+09	22137	0.433833E+05
3	129969107	0.413738E+09	57694	0.105225E+07
4	216269350	0.737800E+09	137254	0.242308E+07
5	295233538	0.110690E+10	1585139	0.374998E+07
6	353590205	0.153664E+10	2094665	0.872056E+07
7	216873864	0.174183E+10	2479423	0.257933E+08
8	272233848	0.200954E+10	2184133	0.263354E+08
9	307956575	0.215904E+10	3243001	0.220052E+08
10	314397706	0.208445E+10	2392517	0.260202E+08
11	332023650	0.204185E+10	4325631	0.198226E+08
12	409182947	0.223014E+10	3764192	0.255708E+08
Average values				
	.242740E+09	0.135623E+10	.185715E+07	0.134616E+08

qtr	long items	long $	commit$	demval$
1	6784	0.460798E+08	0.268584E+08	0.647982E+08
2	6848	0.526533E+08	0.182541E+08	0.674631E+08
3	6868	0.584696E+08	0.327610E+08	0.688074E+08
4	6998	0.658106E+08	0.280799E+08	0.713635E+08
5	7076	0.700979E+08	0.345732E+08	0.682691E+08
6	7131	0.802370E+08	0.241953E+08	0.687910E+08
7	7256	0.862283E+08	0.361052E+08	0.722490E+08
8	7357	0.937105E+08	0.271517E+08	0.717971E+08
9	7446	0.965119E+08	0.338535E+08	0.751302E+08
10	7551	0.100147E+09	0.324282E+08	0.752493E+08
11	7574	0.101470E+09	0.308549E+08	0.795007E+08
12	7668	0.101496E+09	0.363584E+08	0.822326E+08
Average values				
	7213.1	0.794094E+08	0.301228E+08	0.721376E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 680.
Run number 1
migsd= 9905
demsd= 7415

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2541506	0.231570E+08	34	0.472320E+04
2	10281801	0.102696E+09	126	0.539364E+05
3	25315488	0.260864E+09	16238	0.853786E+06
4	49974685	0.492683E+09	24236	0.880672E+06
5	80996688	0.823378E+09	245919	0.275807E+07
6	107459051	0.120902E+10	574835	0.498931E+07
7	138531047	0.149878E+10	3009967	0.140651E+08
8	178893295	0.190253E+10	1076991	0.227413E+08
9	197013760	0.191653E+10	2019329	0.196453E+08
10	224683312	0.181240E+10	868905	0.188402E+08
11	263197874	0.185168E+10	2004274	0.252376E+08
12	281813328	0.215107E+10	4532352	0.188191E+08
Average values				
	.130092E+09	0.117040E+10	.119782E+07	0.107408E+08

qtr	long items	long $	commit$	demval$
1	6743	0.344507E+08	0.291611E+08	0.695378E+08
2	6814	0.418335E+08	0.159512E+08	0.694906E+08
3	6893	0.482171E+08	0.397879E+08	0.716015E+08
4	6956	0.522850E+08	0.234225E+08	0.742740E+08
5	7016	0.622508E+08	0.386655E+08	0.756709E+08
6	7084	0.674213E+08	0.227750E+08	0.779703E+08
7	7203	0.715534E+08	0.421827E+08	0.808892E+08
8	7243	0.728841E+08	0.251430E+08	0.832453E+08
9	7347	0.729121E+08	0.385992E+08	0.835426E+08
10	7377	0.912807E+08	0.240321E+08	0.840625E+08
11	7475	0.959920E+08	0.404104E+08	0.860210E+08
12	7576	0.105143E+09	0.269201E+08	0.851144E+08
Average values				
	7143.9	0.680186E+08	0.305876E+08	0.784517E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 680.
Run number 2
migsd= 6057
demsd= 2873

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	2493086	0.293803E+08	70	0.193057E+05
2	11720918	0.144529E+09	823	0.290057E+05
3	26485553	0.338670E+09	61822	0.926832E+06
4	54886871	0.616199E+09	27146	0.146124E+07
5	98716177	0.899420E+09	439224	0.286557E+07
6	167536453	0.128910E+10	1588763	0.716827E+07
7	236713134	0.165906E+10	1665568	0.232138E+08
8	303784213	0.189486E+10	1135873	0.176405E+08
9	375563016	0.225397E+10	3186032	0.216134E+08
10	439051288	0.257003E+10	2264588	0.195301E+08
11	519475302	0.268924E+10	13598297	0.320252E+08
12	349272170	0.287554E+10	4396667	0.428170E+08
Average values				
	.215475E+09	0.143833E+10	.236374E+07	0.141092E+08

qtr	long items	long $	commit$	demval$
1	6770	0.352684E+08	0.320307E+08	0.717272E+08
2	6827	0.423828E+08	0.179337E+08	0.730873E+08
3	6880	0.613428E+08	0.328463E+08	0.697890E+08
4	6961	0.663205E+08	0.216038E+08	0.694410E+08
5	7043	0.769845E+08	0.318600E+08	0.687841E+08
6	7136	0.825349E+08	0.315538E+08	0.736257E+08
7	7221	0.886186E+08	0.412460E+08	0.742770E+08
8	7302	0.886886E+08	0.304481E+08	0.777732E+08
9	7401	0.979876E+08	0.358653E+08	0.754772E+08
10	7456	0.101899E+09	0.280392E+08	0.769444E+08
11	7513	0.987968E+08	0.318172E+08	0.783776E+08
12	7608	0.105345E+09	0.315250E+08	0.818653E+08
Average values				
	7176.5	0.788475E+08	0.305641E+08	0.742641E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 680.
Run number 3
migsd= 9745
demsd= 3447

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1229193	0.562970E+07	466	0.109090E+05
2	7456279	0.443229E+08	3570	0.345898E+05
3	20156106	0.154647E+09	4325	0.143837E+06
4	38650913	0.336362E+09	4356	0.351960E+06
5	56558049	0.573678E+09	819087	0.329648E+07
6	74391635	0.857322E+09	819630	0.608662E+07
7	99588189	0.111282E+10	628343	0.101192E+08
8	154534825	0.132492E+10	553642	0.119016E+08
9	214916568	0.155468E+10	1431553	0.223181E+08
10	284047637	0.163908E+10	1313332	0.135104E+08
11	348687255	0.172587E+10	1482612	0.182092E+08
12	410166122	0.185977E+10	5817293	0.202034E+08
Average values				
	.142532E+09	0.932425E+09	.107318E+07	0.884885E+07

qtr	long items	long $	commit$	demval$
1	6739	0.350551E+08	0.266714E+08	0.675435E+08
2	6832	0.477189E+08	0.165138E+08	0.615278E+08
3	6918	0.652548E+08	0.244861E+08	0.585104E+08
4	7042	0.746898E+08	0.181838E+08	0.580336E+08
5	7104	0.769650E+08	0.288904E+08	0.616822E+08
6	7196	0.819530E+08	0.237105E+08	0.610628E+08
7	7317	0.913981E+08	0.260590E+08	0.596535E+08
8	7429	0.101977E+09	0.229528E+08	0.575687E+08
9	7471	0.106249E+09	0.257269E+08	0.612901E+08
10	7555	0.112168E+09	0.274063E+08	0.625208E+08
11	7643	0.117152E+09	0.295386E+08	0.632557E+08
12	7696	0.122371E+09	0.286022E+08	0.642338E+08
Average values				
	7245.2	0.860827E+08	0.248952E+08	0.614069E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 680.
Run number 4
migsd= 1075
demsd= 1175

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	3468526	0.491814E+08	649	0.192751E+05
2	14274169	0.196455E+09	687	0.202392E+06
3	33268002	0.443537E+09	52906	0.158350E+07
4	56835701	0.814258E+09	36192	0.178273E+07
5	87617272	0.123809E+10	934104	0.412466E+07
6	122444066	0.170620E+10	701907	0.118944E+08
7	151621635	0.191242E+10	1652616	0.300323E+08
8	196176092	0.217096E+10	877674	0.187903E+08
9	226767443	0.229222E+10	1849153	0.323842E+08
10	220122511	0.239260E+10	1804297	0.257651E+08
11	249629298	0.247874E+10	2342893	0.252846E+08
12	324575516	0.267513E+10	1558776	0.175272E+08
Average values				
	.140567E+09	0.153082E+10	.989321E+06	0.141159E+08

qtr	long items	long $	commit$	demval$
1	6772	0.351195E+08	0.317279E+08	0.726718E+08
2	6843	0.403238E+08	0.176053E+06	0.751768E+08
3	6962	0.451072E+08	0.398148E+08	0.774171E+08
4	7061	0.540997E+08	0.227558E+08	0.770944E+08
5	7099	0.602429E+08	0.359829E+08	0.742661E+08
6	7202	0.685258E+08	0.270682E+08	0.742950E+08
7	7249	0.713896E+08	0.384106E+08	0.770744E+08
8	7367	0.786726E+08	0.298529E+08	0.808415E+08
9	7402	0.873984E+08	0.397102E+08	0.791643E+08
10	7485	0.852741E+08	0.310675E+08	0.802358E+08
11	7559	0.981593E+08	0.367379E+08	0.792118E+08
12	7629	0.109617E+09	0.309524E+08	0.765405E+08
Average values				
	7219.2	0.695108E+08	0.318072E+08	0.769991E+08

Model output

One quarter information lag
Variable lead time
Implied shortage factor= 680.
Run number 5
migsd= 7099
demsd= 7395

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	9775694	0.367283E+08	4	0.143822E+04
2	55367771	0.175336E+09	22128	0.425782E+05
3	129968608	0.412888E+09	57678	0.102801E+07
4	216268703	0.736698E+09	137318	0.255255E+07
5	295230966	0.110485E+10	1584967	0.344686E+07
6	353587431	0.153488E+10	2094865	0.912193E+07
7	216870263	0.173948E+10	2479405	0.257679E+08
8	272228937	0.200680E+10	2184120	0.263345E+08
9	307940984	0.215493E+10	3242594	0.213216E+08
10	314347812	0.203033E+10	2392894	0.267417E+08
11	331960340	0.197103E+10	4324961	0.188741E+08
12	409133693	0.222682E+10	3763390	0.255406E+08
Average values				
	.242723E+09	0.134423E+10	.185703E+07	0.133978E+08

qtr	long items	long $	commit$	demval$
1	6783	0.465257E+08	0.279129E+08	0.647982E+08
2	6848	0.531360E+08	0.174810E+08	0.674631E+08
3	6868	0.592416E+08	0.338042E+08	0.688074E+08
4	6998	0.666141E+08	0.283497E+08	0.713635E+08
5	7076	0.712613E+08	0.343898E+08	0.682691E+08
6	7131	0.814057E+08	0.237123E+08	0.687910E+08
7	7256	0.874662E+08	0.370491E+08	0.722490E+08
8	7357	0.950068E+08	0.266126E+08	0.717971E+08
9	7445	0.978172E+08	0.346036E+08	0.751302E+08
10	7551	0.101456E+09	0.317504E+08	0.752493E+08
11	7574	0.102748E+09	0.317626E+08	0.795007E+08
12	7668	0.102949E+09	0.357309E+08	0.822326E+08
Average values				
	7212.9	0.804690E+08	0.302633E+08	0.721376E+08

Appendix C: MIGSIM Output with No Item Migration

Model output, no migration

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 1
migsd= 9905
demsd= 7415

Quarter 1 through 12

FROM/TO	X	T	P	M	OUT
X	10800	0	0	0	0
T	0	2029	0	0	0
P	0	0	822	0	0
M	0	0	0	188	0
IN	0	0	0	0	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	37	0.571520E+04	37	0.571520E+04
2	9	0.202026E+04	9	0.194229E+04
3	39	0.788550E+04	39	0.796348E+04
4	10	0.370353E+04	10	0.354760E+04
5	41	0.104495E+05	41	0.105514E+05
6	10	0.508932E+04	10	0.499167E+04
7	40	0.729216E+04	40	0.729216E+04
8	12	0.213670E+04	12	0.213670E+04
9	10	0.411847E+04	10	0.411847E+04
10	3	0.248897E+04	3	0.248897E+04
11	1	0.162409E+04	1	0.162409E+04
12	3	0.172983E+04	3	0.172983E+04
Average values				
	.179167E+02	0.452113E+04	.179167E+02	0.450849E+04

qtr	long items	long $	commit$	demval$
1	6380	0.289579E+08	0.225930E+08	0.664603E+08
2	6329	0.286041E+08	0.847471E+07	0.664603E+08
3	6281	0.282801E+08	0.217126E+08	0.664603E+08
4	6234	0.279866E+08	0.897619E+07	0.664603E+08
5	6199	0.277107E+08	0.222510E+08	0.664603E+08
6	6169	0.274546E+08	0.977319E+07	0.664603E+08
7	6142	0.272180E+08	0.225183E+08	0.664603E+08
8	6113	0.270024E+08	0.996617E+07	0.664603E+08
9	6080	0.268043E+08	0.229681E+08	0.664603E+08
10	6049	0.266154E+08	0.972604E+07	0.664603E+08
11	6027	0.264359E+08	0.227223E+08	0.664603E+08
12	6011	0.262622E+08	0.100716E+08	0.664603E+08
Average values				
	6167.8	0.274443E+08	0.159794E+08	0.664603E+08

Appendix D: MIGSIM Output with Altered Transition Matrix

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 1
migsd= 9905
demsd= 7415

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10305	127	0	0	368
T	89	1822	50	0	68
P	9	32	750	6	25
M	0	0	12	169	7
IN	423	29	12	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10294	132	0	0	400
T	88	1816	45	0	61
P	14	37	745	11	17
M	1	0	5	168	4
IN	434	31	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10302	146	0	0	383
T	85	1802	66	0	63
P	4	42	734	9	19
M	0	0	7	174	1
IN	421	29	12	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10296	119	0	0	397
T	68	1830	65	0	56
P	9	37	746	13	14
M	0	0	6	171	9
IN	429	29	13	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10270	129	0	0	403
T	71	1821	61	0	62
P	5	42	750	10	23
M	2	0	9	174	2
IN	443	31	13	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10240	127	0	0	424
T	84	1806	57	0	76
P	13	36	755	9	20
M	2	0	6	176	3
IN	473	33	14	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10274	126	0	0	412
T	78	1804	53	0	61
P	7	40	754	6	25
M	0	0	8	180	0
IN	449	32	13	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10267	139	0	0	402
T	73	1793	70	0	66
P	9	38	759	8	20
M	2	0	6	177	4
IN	444	31	13	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	10270	115	0	0	410
T	94	1785	67	0	55
P	7	[illegible]	783	5	12
M	1	[illegible]	4	176	5
IN	434	31	13	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	10313	113	0	0	380
T	85	1766	77	0	46
P	2	30	805	19	11
M	3	0	9	169	3
IN	398	28	12	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	10248	121	0	0	432
T	85	1734	49	0	69
P	7	38	831	11	16
M	2	0	12	170	7
IN	473	33	14	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	10246	137	0	0	432
T	78	1732	53	0	63
P	6	38	830	12	20
M	1	1	8	170	4
IN	469	33	14	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	945692	0.126324E+08	234	0.842305E+05
2	3525220	0.717347E+08	9	0.200911E+04
3	8741310	0.189826E+09	5052	0.111563E+07
4	14935841	0.336460E+09	57495	0.806654E+06
5	17012340	0.531470E+09	115572	0.280040E+07
6	22054834	0.641250E+09	103812	0.740692E+07
7	26806805	0.554045E+09	151280	0.340123E+07
8	32162440	0.530814E+09	220937	0.647506E+07
9	31871028	0.389965E+09	292959	0.331612E+07
10	39808261	0.410497E+09	208449	0.334182E+07
11	53754037	0.487365E+09	330458	0.428580E+07
12	67563484	0.416048E+09	345582	0.317873E+07
Average values				
	.265984E+08	0.381009E+09	.152653E+06	0.301788E+07

qtr	long items	long $	commit$	demval$
1	6738	0.377583E+08	0.286993E+08	0.664219E+08
2	6831	0.431877E+08	0.192768E+08	0.664595E+08
3	6896	0.490968E+08	0.302606E+08	0.660427E+08
4	6980	0.520139E+08	0.213701E+08	0.688639E+08
5	7086	0.630492E+08	0.279820E+08	0.652501E+08
6	7204	0.683329E+08	0.184646E+08	0.655421E+08
7	7297	0.716661E+08	0.263014E+08	0.615917E+08
8	7364	0.758244E+08	0.188127E+08	0.622018E+08
9	7499	0.803678E+08	0.261165E+08	0.627382E+08
10	7537	0.832501E+08	0.247648E+08	0.655964E+08
11	7675	0.886545E+08	0.274637E+08	0.656819E+08
12	7755	0.943743E+08	0.207429E+08	0.633496E+08
Average values				
	7238.5	0.673146E+08	0.241880E+08	0.649783E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 2
migsd= 6057
demsd= 2873

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10270	132	0	0	398
T	91	1822	51	0	65
P	7	33	754	12	16
M	0	0	6	177	5
IN	437	31	13	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10299	105	0	0	401
T	91	1807	65	0	55
P	8	35	763	7	11
M	0	0	6	180	6
IN	427	29	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10322	127	0	0	376
T	80	1775	68	0	53
P	5	39	774	9	20
M	1	0	8	177	4
IN	409	29	12	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10308	111	0	0	398
T	73	1775	55	0	67
P	7	39	787	9	20
M	1	0	6	179	3
IN	441	31	13	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10303	127	0	0	400
T	61	1778	59	0	58
P	11	39	782	11	18
M	1	0	8	174	8
IN	437	31	13	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10305	138	0	0	370
T	77	1761	67	0	70
P	7	46	777	12	20
M	1	1	6	175	5
IN	419	29	12	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10273	126	0	0	410
T	75	1793	58	0	49
P	10	30	789	12	21
M	0	0	4	182	4
IN	437	31	13	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10246	137	0	0	412
T	81	1779	50	0	70
P	15	34	778	17	20
M	1	0	6	183	7
IN	459	32	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	10255	113	0	0	434
T	79	1781	50	0	72
P	3	46	770	10	19
M	3	1	6	185	8
IN	482	34	14	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	10242	144	0	0	436
T	96	1780	46	0	53
P	8	35	766	9	22
M	1	0	9	185	3
IN	464	33	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	10292	104	0	0	415
T	86	1790	51	0	65
P	7	33	769	7	19
M	1	0	6	182	8
IN	458	32	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	10307	132	0	0	405
T	90	1747	64	0	58
P	5	31	776	16	11
M	0	0	8	178	6
IN	434	31	13	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	843740	0.111294E+08	42	0.645646E+04
2	4703975	0.789890E+08	272	0.132281E+06
3	12456269	0.200326E+09	20891	0.739525E+06
4	22178654	0.373961E+09	66983	0.120933E+07
5	25748123	0.440309E+09	206173	0.441478E+07
6	30376992	0.380397E+09	211365	0.369124E+07
7	27989629	0.402363E+09	279266	0.263537E+07
8	38866585	0.553414E+09	194813	0.330837E+07
9	55037065	0.692731E+09	289974	0.493757E+07
10	68570351	0.688143E+09	601178	0.620585E+07
11	50226906	0.431206E+09	786048	0.341725E+07
12	28426053	0.384903E+09	536442	0.528580E+07
Average values				
	.304520E+08	0.386489E+09	.266121E+06	0.300532E+07

qtr	long items	long $	commit$	demval$
1	6754	0.348265E+09	0.228580E+08	0.689445E+08
2	6860	0.345465E+08	0.165047E+08	0.690835E+08
3	6924	0.402942E+08	0.321020E+08	0.699080E+08
4	7039	0.460880E+08	0.178733E+08	0.702621E+08
5	7123	0.585058E+08	0.297278E+08	0.665740E+08
6	7210	0.629959E+08	0.226293E+08	0.679511E+08
7	7311	0.661986E+08	0.317438E+08	0.702960E+08
8	7405	0.707538E+08	0.229567E+08	0.715523E+08
9	7544	0.817237E+08	0.277354E+08	0.680565E+08
10	7623	0.860339E+08	0.204825E+08	0.669559E+08
11	7707	0.861647E+08	0.238427E+08	0.654998E+08
12	7772	0.959286E+08	0.237031E+08	0.627131E+08
Average values				
	7272.7	0.636717E+08	0.251725E+08	0.681414E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 3
migsd= 9745
demsd= 3447

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10278	128	0	0	394
T	87	1836	49	0	57
P	6	30	761	5	20
M	0	0	7	176	5
IN	429	29	13	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10275	116	0	0	409
T	84	1831	59	0	49
P	8	37	768	3	14
M	0	0	13	169	2
IN	428	29	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10253	121	0	0	421
T	77	1808	67	0	61
P	10	35	776	7	25
M	0	0	8	161	6
IN	463	33	14	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10276	120	0	0	407
T	95	1787	50	0	65
P	11	37	786	9	22
M	2	0	8	158	3
IN	449	32	13	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10330	113	0	0	390
T	96	1775	52	0	53
P	8	33	780	18	18
M	0	0	10	152	8
IN	424	29	12	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10279	151	0	0	428
T	84	1774	51	0	41
P	7	48	771	8	20
M	1	0	11	154	7
IN	448	32	13	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10243	132	0	0	444
T	89	1791	59	0	66
P	9	35	776	6	20
M	0	0	10	151	4
IN	482	34	14	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10300	114	0	0	409
T	83	1791	53	0	65
P	9	37	784	13	16
M	0	0	12	141	7
IN	442	32	13	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	10300	125	0	0	416
T	80	1776	55	0	63
P	6	46	777	15	18
M	2	0	6	142	7
IN	454	32	13	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	10319	103	0	0	420
T	93	1772	49	0	65
P	8	34	777	9	23
M	1	0	7	148	4
IN	463	33	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	10370	112	0	0	402
T	80	1752	50	0	50
P	7	46	756	10	28
M	0	0	8	147	5
IN	447	31	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	10381	135	0	0	388
T	87	1767	45	0	42
P	10	33	756	11	17
M	1	0	5	152	2
IN	406	29	12	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	898792	0.662445E+07	203	0.645485E+04
2	6230199	0.378360E+08	22	0.657475E+05
3	16364366	0.964846E+08	6204	0.342389E+06
4	31330576	0.192325E+09	195975	0.466941E+06
5	37219855	0.266452E+09	247432	0.268739E+07
6	41803292	0.290681E+09	151295	0.184145E+07
7	27979324	0.352052E+09	444055	0.227154E+07
8	30626186	0.423584E+09	310950	0.342901E+07
9	26269524	0.435614E+09	264029	0.457315E+07
10	24104621	0.382612E+09	147213	0.323384E+07
11	28009975	0.397806E+09	119094	0.224600E+07
12	36225170	0.517438E+09	209119	0.455577E+07
Average values				
	.255885E+08	0.283292E+09	.174633E+06	0.214331E+07

qtr	long items	long $	commit$	demval$
1	6756	0.347470E+08	0.286349E+08	0.670402E+08
2	6842	0.423822E+08	0.152865E+08	0.658356E+08
3	6932	0.470807E+08	0.278770E+06	0.662889E+08
4	7056	0.571007E+08	0.169866E+08	0.636304E+08
5	7163	0.624695E+08	0.287129E+08	0.654820E+08
6	7276	0.666713E+08	0.174967E+08	0.608313E+08
7	7378	0.698492E+08	0.244580E+08	0.590433E+08
8	7474	0.749691E+08	0.176936E+06	0.576992E+08
9	7565	0.800503E+08	0.279406E+08	0.572132E+08
10	7681	0.835526E+08	0.174762E+08	0.570819E+08
11	7767	0.870072E+08	0.248762E+08	0.576838E+08
12	7832	0.944590E+08	0.207804E+08	0.589281E+08
Average values				
	7310.2	0.666949E+08	0.223516E+08	0.613365E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 4
migsd= 1075
demsd= 1175

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10262	120	0	0	418
T	82	1830	57	0	60
P	5	44	749	9	15
M	3	0	13	169	3
IN	448	32	13	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10280	116	0	0	404
T	90	1822	58	0	56
P	4	28	762	6	32
M	0	0	9	165	7
IN	451	32	13	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10260	133	0	0	432
T	88	1806	48	0	56
P	6	52	755	13	16
M	2	0	9	157	6
IN	461	32	14	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10271	113	0	0	433
T	81	1802	68	0	72
P	4	45	751	6	20
M	0	2	5	161	5
IN	479	34	14	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
	10291	131	0	0	413
	97	1770	58	0	71
P	8	36	765	10	19
M	2	0	6	157	5
IN	459	32	13	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10282	137	0	0	438
T	90	1773	47	0	59
P	6	36	764	13	23
M	0	0	7	160	3
IN	473	33	14	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10333	136	0	0	382
T	76	1788	60	0	55
P	8	35	754	20	15
M	0	0	8	164	4
IN	412	29	12	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10266	123	0	0	440
T	80	1791	57	0	60
P	8	37	756	12	21
M	1	0	8	170	8
IN	478	34	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	10298	121	0	0	414
T	81	1793	60	0	51
P	7	47	741	16	24
M	0	0	9	172	4
IN	444	31	13	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	10304	108	0	0	418
T	94	1780	59	0	59
P	7	43	744	5	24
M	0	0	9	174	8
IN	459	32	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	10298	144	0	0	422
T	76	1784	56	0	47
P	5	50	734	11	26
M	1	0	8	170	3
IN	449	32	13	3	0

Quarter 12

FROM/TO	X	T	P	M	OUT
X	10297	117	0	0	415
T	79	1812	53	0	66
P	5	41	748	5	12
M	0	1	6	173	4
IN	449	32	13	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	777050	0.116193E+08	60	0.754452E+05
2	3609818	0.656018E+08	487	0.116920E+06
3	9055960	0.163718E+09	1349	0.494654E+06
4	14692218	0.291212E+09	95199	0.850753E+06
5	16784719	0.373527E+09	77391	0.409097E+07
6	22465903	0.361270E+09	132143	0.288210E+07
7	29306709	0.387891E+09	196283	0.297726E+07
8	36508933	0.410831E+09	220136	0.339814E+07
9	36920797	0.549096E+09	380692	0.286347E+07
10	32490895	0.649048E+09	326865	0.519071E+07
11	34251636	0.697912E+09	296468	0.644996E+07
12	37285456	0.561804E+09	366267	0.609291E+07
Average values				
	.228458E+08	0.376961E+09	.174445E+06	0.295694E+07

qtr	long items	long $	commit$	demval$
1	6770	0.372332E+08	0.318705E+08	0.672899E+08
2	6862	0.502979E+08	0.184890E+08	0.656175E+08
3	6970	0.579269E+08	0.267221E+08	0.619095E+08
4	7065	0.684234E+08	0.173768E+08	0.601227E+08
5	7153	0.716954E+08	0.246031E+08	0.601500E+08
6	7246	0.744168E+08	0.211700E+08	0.617959E+08
7	7287	0.753089E+08	0.301146E+08	0.642402E+08
8	7442	0.795350E+08	0.221597E+08	0.669092E+08
9	7524	0.835542E+08	0.316032E+08	0.687424E+08
10	7630	0.912476E+08	0.185278E+08	0.637422E+08
11	7702	0.957859E+08	0.250479E+08	0.616292E+08
12	7770	0.101796E+09	0.173667E+08	0.593986E+08
Average values				
	7285.1	0.739351E+08	0.237543E+08	0.634623E+08

Model output

No information lag
Constant lead time
Implied shortage factor= 580.
Run number 5
migsd= 7099
demsd= 7395

Quarter 1

FROM/TO	X	T	P	M	OUT
X	10203	139	0	0	458
T	82	1815	74	0	58
P	8	35	756	5	18
M	1	1	7	174	5
IN	487	34	14	3	0

Quarter 2

FROM/TO	X	T	P	M	OUT
X	10224	125	0	0	432
T	86	1811	62	0	65
P	12	38	764	12	25
M	0	1	6	167	8
IN	479	34	14	3	0

Quarter 3

FROM/TO	X	T	P	M	OUT
X	10264	134	0	0	403
T	63	1817	61	0	68
P	7	43	770	8	18
M	1	0	5	175	1
IN	443	31	13	3	0

Quarter 4

FROM/TO	X	T	P	M	OUT
X	10216	142	0	0	420
T	77	1818	61	0	69
P	8	42	774	6	19
M	1	0	7	169	9
IN	467	33	14	3	0

Quarter 5

FROM/TO	X	T	P	M	OUT
X	10184	135	0	0	450
T	91	1833	60	0	51
P	11	28	787	8	22
M	2	0	7	164	5
IN	477	34	14	3	0

Quarter 6

FROM/TO	X	T	P	M	OUT
X	10231	129	0	0	405
T	100	1834	43	0	53
P	14	30	793	8	23
M	1	1	6	163	4
IN	438	31	13	3	0

Quarter 7

FROM/TO	X	T	P	M	OUT
X	10226	133	0	0	425
T	95	1827	57	0	46
P	7	33	781	12	22
M	2	1	4	161	6
IN	451	32	13	3	0

Quarter 8

FROM/TO	X	T	P	M	OUT
X	10208	138	0	0	435
T	88	1810	61	0	67
P	10	39	780	8	18
M	0	0	8	164	4
IN	473	33	14	3	0

Quarter 9

FROM/TO	X	T	P	M	OUT
X	10235	127	0	0	417
T	96	1811	51	0	62
P	7	31	794	9	22
M	0	0	4	164	7
IN	459	32	13	3	0

Quarter 10

FROM/TO	X	T	P	M	OUT
X	10252	101	0	0	444
T	70	1808	52	0	71
P	4	38	801	6	13
M	1	0	4	166	5
IN	482	34	14	3	0

Quarter 11

FROM/TO	X	T	P	M	OUT
X	10272	125	0	0	412
T	82	1780	50	0	69
P	8	34	801	6	22
M	1	0	7	163	4
IN	458	32	13	3	0

Quarter 12

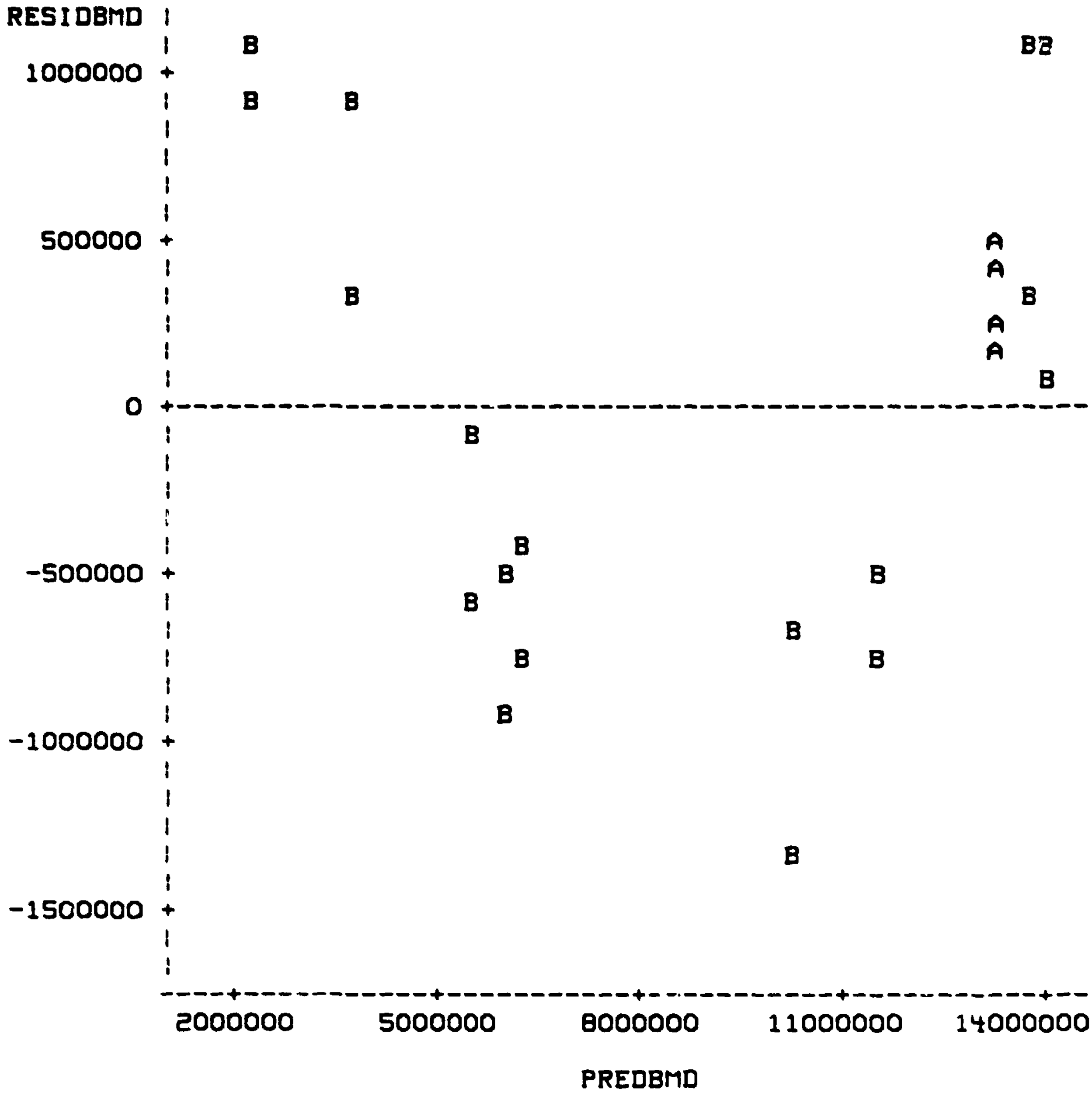
FROM/TO	X	T	P	M	OUT
X	10250	133	0	0	438
T	92	1770	55	0	54
P	13	45	783	15	15
M	0	0	8	157	7
IN	464	33	14	3	0

qtr	bkord-days	bkord-day$	bkord-max	bkord-max$
1	1489594	0.199849E+08	37	0.545608E+04
2	9723043	0.105411E+09	359	0.103793E+06
3	23876663	0.269367E+09	48909	0.921749E+06
4	35559184	0.411866E+09	235774	0.200822E+07
5	35870655	0.555594E+09	287824	0.357920E+07
6	32094609	0.599420E+09	208744	0.485505E+07
7	28304119	0.485640E+09	354933	0.688712E+07
8	22227702	0.336574E+09	150069	0.272196E+07
9	24696686	0.354556E+09	183663	0.299757E+07
10	28261902	0.384840E+09	142946	0.291554E+07
11	30571644	0.414526E+09	466498	0.368814E+07
12	22706904	0.355353E+09	138311	0.353407E+07
Average values				
	.246152E+08	0.357761E+09	.184839E+06	0.285149E+07

qtr	long items	long $	commit$	demval$
1	6781	0.345923E+08	0.324289E+08	0.689508E+08
2	6879	0.392488E+08	0.187215E+08	0.710893E+08
3	6954	0.475747E+08	0.331402E+08	0.689218E+08
4	7077	0.525091E+08	0.157839E+08	0.692056E+08
5	7209	0.570918E+08	0.285360E+08	0.654399E+08
6	7284	0.612844E+08	0.165965E+08	0.645746E+08
7	7418	0.651551E+08	0.298128E+08	0.656762E+08
8	7528	0.698415E+08	0.183935E+08	0.631996E+08
9	7592	0.720133E+08	0.286491E+08	0.647411E+08
10	7683	0.746994E+08	0.187357E+08	0.648791E+08
11	7756	0.834592E+08	0.244510E+08	0.606463E+08
12	7859	0.867711E+08	0.239329E+08	0.638898E+08
Average values				
	7335.0	0.620201E+08	0.240985E+08	0.659345E+08

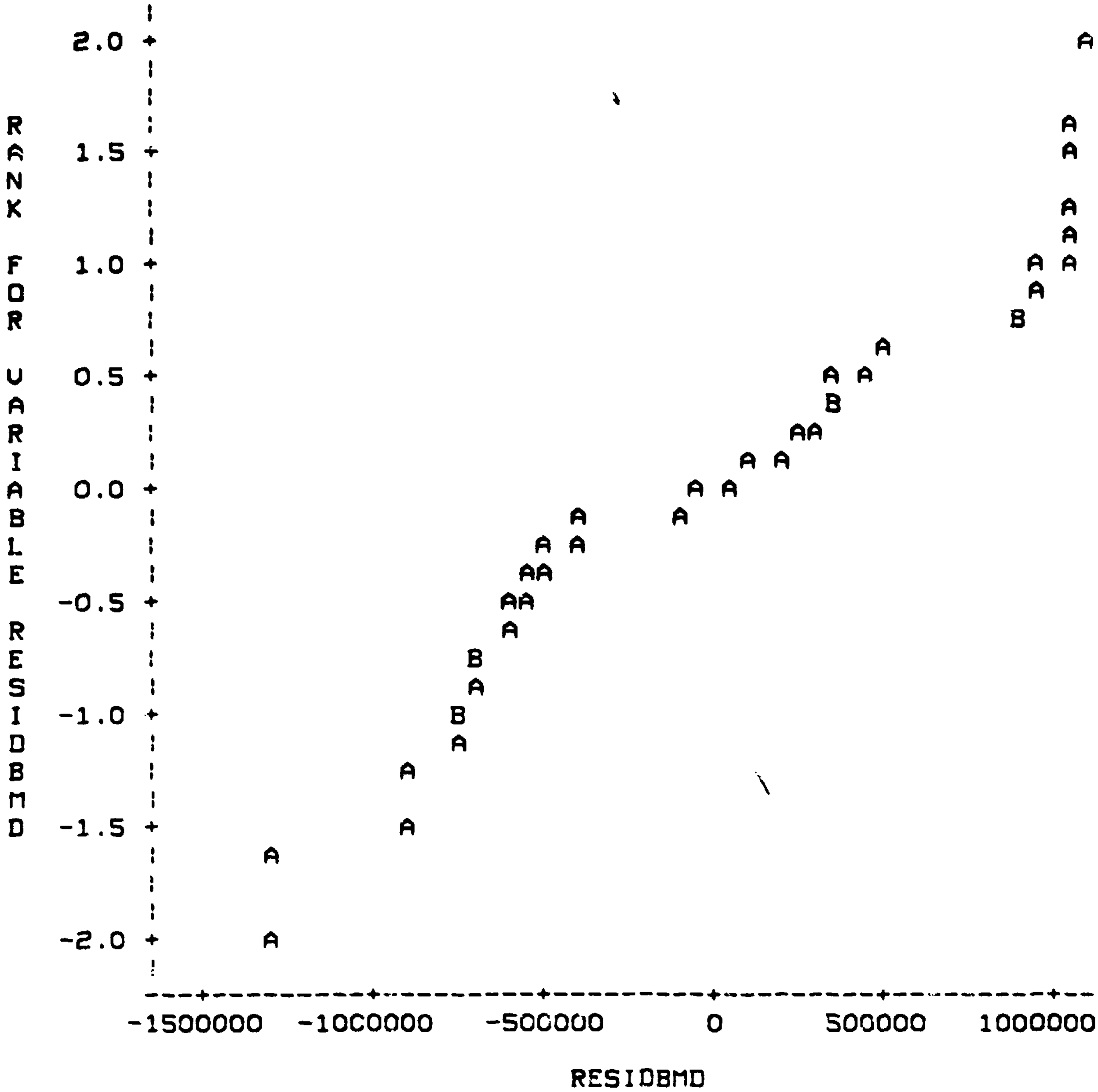
Appendix E: SAS Residual Plots

PLOT OF RESIDBMD*PREDBMD   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



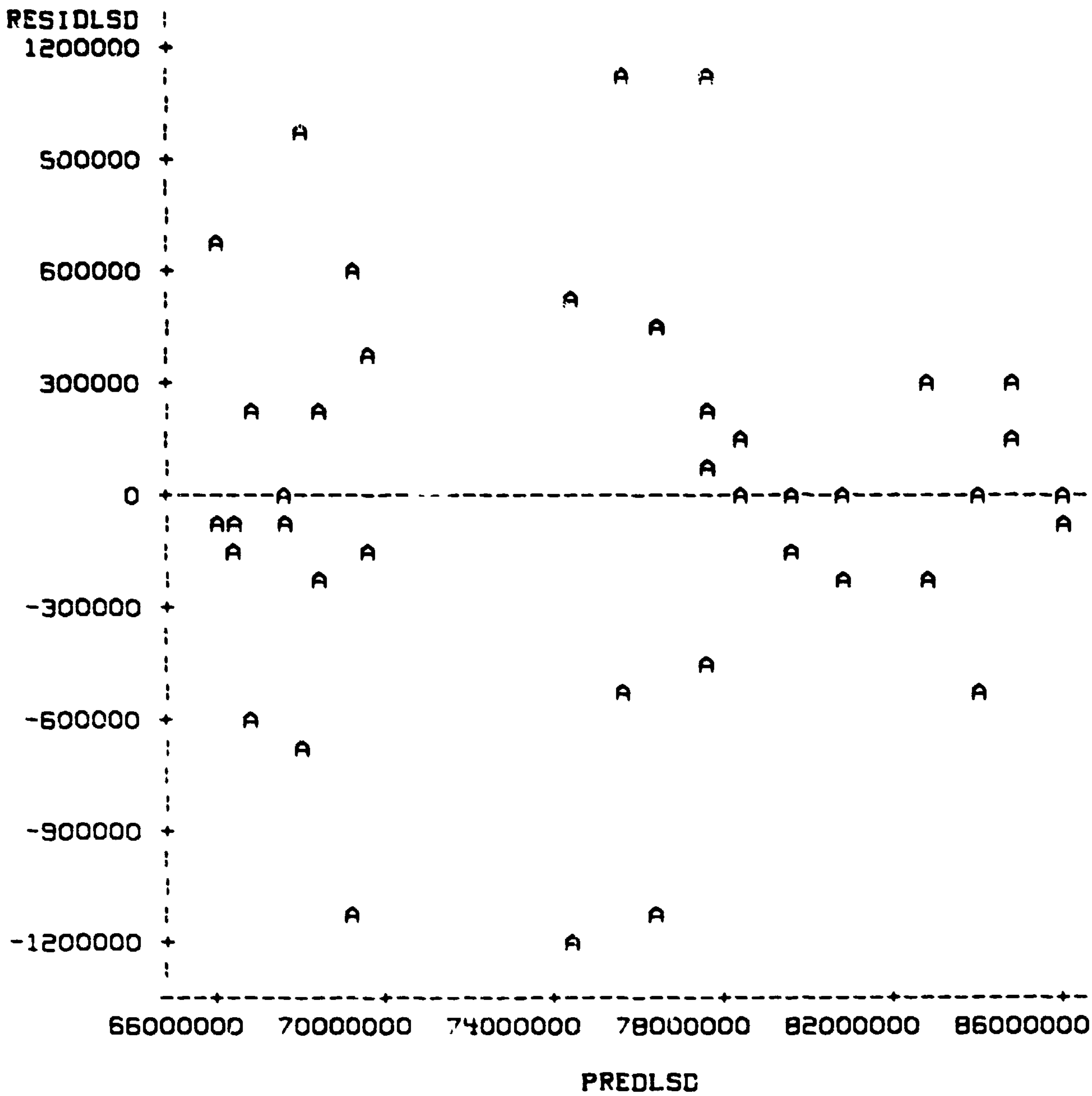
Predicted vs. Residual Values for Backorders (14:992)

PLOT OF BMDRANK*RESIDBMD LEGEND: A = 1 OBS, B = 2 OBS,
ETC.

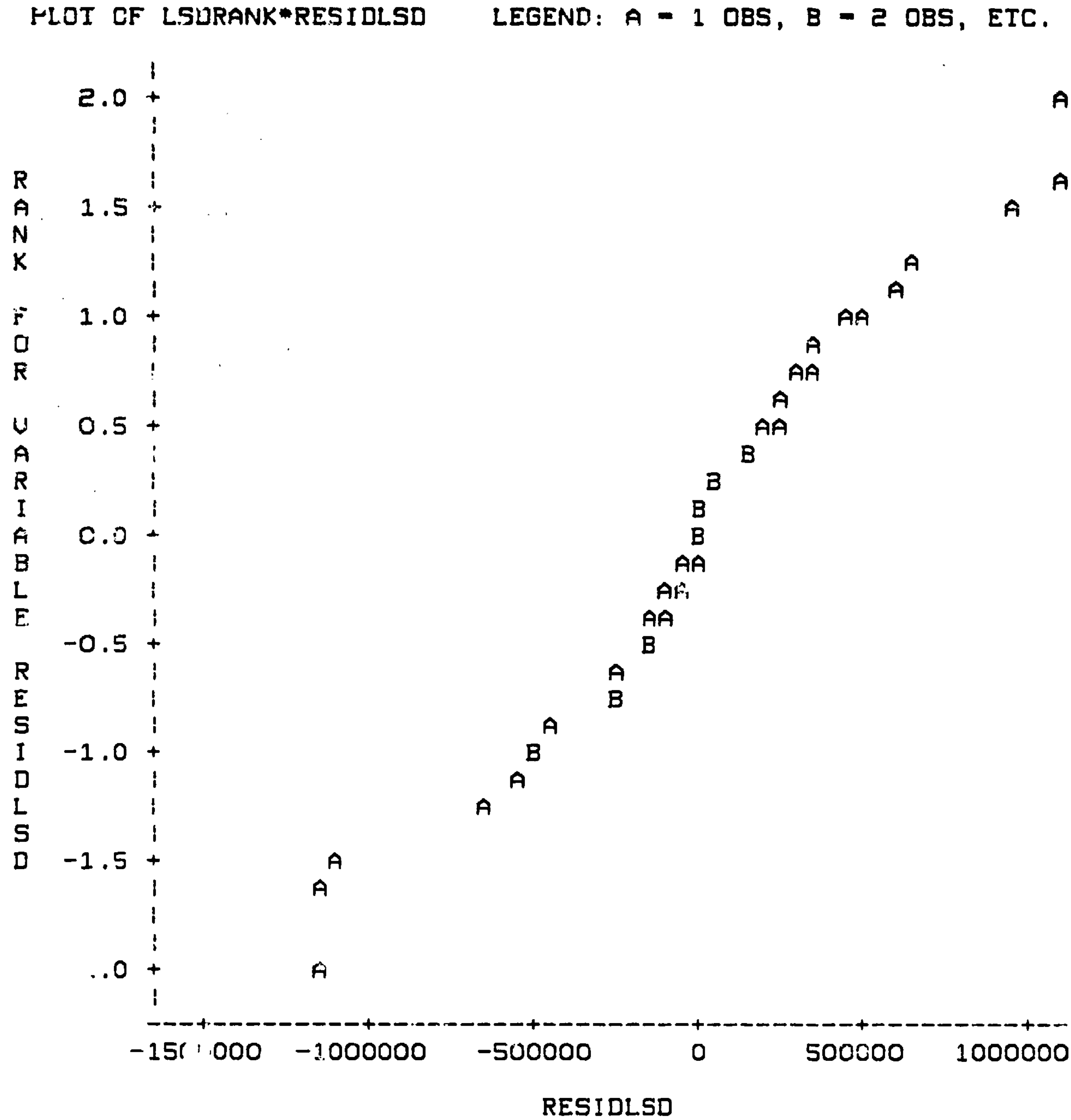


Ranked Residual Plot for Backorders (15:648)

PLOT OF RESIDLSD*PREDLSD   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



Predicted vs. Residual Values for Long Supply (14:992)



Ranked Residual Plot for Long Supply (15:648)

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