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STOCKAGE POLICY COST SIMULATION FOR DLA HAZARDOUS AND NONHAZARDOUS SHELF-LIFE ITEMS

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ABSTRACT

Hazardous shelf-life items present complex and challenging managerial problems for both government and industry. We modeled the current and alternative stockage policies for Defense Logistics Agency hazardous shelf-life items with a validated stochastic simulation. We used current government regulations and cost estimates to track procuring, receiving, inspecting, holding and disposing costs. Demands and returns were generated by empirical distributions based on historical data. The results indicate that a direct delivery from vendor to customer policy with adjustments to reorder points and stockage objectives was the best alternative in terms of supply availability and total operating cost. When direct delivery was not possible, the next best alternative was to establish a minimum buy quantity with a conservative stockage objective and to place limits on the economic order quantity and returns.

1. INTRODUCTION

Shelf-life stocks are items which deteriorate over time. They present unique and difficult managerial problems for both industry and government. Shelf-life items require intensified management techniques to insure that they are issued in a usable condition. The management techniques involve intensified inspections, refined classification procedures, reduced holding times, shortened lead times, complicated exception processing, detailed material handling policies, and well defined disposal procedures.

Management of shelf-life items represents a considerable expense for the Department of Defense. The Department of Defense maintains approximately 1.6 billion dollars worth of shelf-life stocks and disposes of over 100 million dollars of shelf-life material annually. The Defense Logistics Agency (DLA) manages approximately 30,000 shelf-life items. Of the 609.5 million dollars worth of shelf-life stocks held in the DLA inventory, approximately 3.4 million dollars of this stock is sent to wholesale disposal annually. Approximately 5 percent of these disposals are for hazardous items.

When the shelf-life items are also hazardous, management problems are compounded. Hazardous items are expensive to manage because they require specialized labeling, packaging, transportation, storage, and inspections. Material handling expenses for hazardous items are approximately twice that for nonhazardous materials.

Disposal of hazardous materials is an area of substantial public concern. Regulations governing hazardous disposals have increased dramatically over the past 10 years. According to figures provided by the Defense Reutilization and Marketing Service, the administrative costs for disposing of hazardous materials are approximately 10 times higher than for nonhazardous materials.

Effective management of shelf-life inventories requires a balance among procurement, receipt, holding, and disposal costs while maintaining high supply availability. Current DLA stockage policies maintain high supply availability, but generate excessive inventories and expiration of the shelf-life. The purpose of this study is to determine if current shelf-life stockage policies can be modified to reduce total operating costs while maintaining current levels of supply availability.

2. APPROACH

2.1 Scope

We limited the study to DLA managed replenishment demand shelf-life items. We excluded items which did not have a valid forecasted demand. We included nonhazardous shelf-life items in our statistical validation in section 3.1, but the comparison of alternatives in section 3.2 concentrated on only hazardous items.

2.2 Model Description

We developed the Shelf-Life Inventory Policy Simulation (SLIPS) to evaluate the current and alternative shelf-life stockage policies. SLIPS is a structured stochastic simulation written in SIMSCRIPT. The model is based on detailed historical data and government regulatory procedures. We attempted to, but could not fit theoretical distributions to our demand and returns data. Therefore, we used historical data to develop empirical distributions of demand interarrival times, requisition sizes, and returns. Shelf-life stock is procured, received, inspected, issued, and disposed of in the model based on current government regulations and procedures (Defense General Supply Center 1987, Defense Logistics Agency 1982, 1983, Department of Defense 1986, and Orchowsky, Kirchoff, and Rider 1986).

The model reads item characteristics and empirical distribution data for individual items, then tracks the procuring, receiving, holding, inspecting, and disposal for that item over a ten year period. The simulation randomly generates demands from empirical distributions. SLIPS determines whether to issue stock from the depot, direct deliver the stock, or backorder the stock. After each demand, the simulation checks the stock position against the reorder point. If a procurement is needed, the simulation generates a buy and schedules a receipt or multiple receipts. When the receipt arrives, the model determines the type of receipt and calculates receiving costs. The simulation fills the backorders and stows the remaining stock in either bin or bulk storage. Stocks are reviewed monthly to determine if they need inspection or disposal. The probability that the stock passes the inspection depends on its age. The simulation randomly generates customer returns from empirical distributions based on historical data. We inspect the returns and randomly determine if the returns are in usable condition. If usable, the returned stock is used to fill backorders and the remaining stock is stored in the depot. The model disposes of all unusable stock which fails an inspection or has no remaining shelf-life.

After all the items have been simulated, the model calculates and displays system costs and dollar values by year and for a steady state period. The costs and dollar values are broken out by type of expense, such as holding costs and disposal dollars, to help identify which type of costs and dollar values are dominant. The model calculates and displays the averages and standard deviations of the annual system costs and dollar values for the replications.

2.3 Sampling

We selected a 1 percent random sample of all shelf-life items for validation runs and a 10 percent random sample of hazardous shelf-life items for evaluating alternatives. We compared statistics for items included in and excluded from the samples to insure that the samples were representative. We found that the items included in and excluded from the sample were not significantly different at the .05 level of probability.

2.4 Validation/Credibility Assessment

We developed a model of the current system and assessed the credibility of the model using the following methods (Balci 1986):

1. We examined the model's policies and procedures to insure that they complied with current government regulations.

2. We consulted with experts to validate our cost figures and model.

3. We checked the model's cost figures against operating budget figures and cost figures from other studies to determine if they were feasible.

4. We validated the model's policies and procedures with historical data.

5. We performed statistical validation. For example, we determined if actual data were within the 95 percent confidence intervals of the simulation results.

6. We performed graph-based analyses to validate the empirical distributions and the stability of our simulation results.

7. We met with system programmers, managers, and program directors to determine if the proposed alternatives were feasible and implementable.

8. The model was subjected to peer review by other analysts and experienced simulators.

2.5 Our Proposed Alternatives

We modeled the current system and then tested alternatives to the present stockage policies. The alternative policies attempt to reduce total operating costs and increase supply availability by modifying current buying, returning, and delivering procedures.

2.501 Apply The Medical Stockage Objective To All DLA Items

We applied the DLA medical stockage objective policies to all DLA items in alternative M. The stockage objective is the buy-up-to quantity for shelf-life items and is based on the item's shelf-life, forecasted demand, war reserves, delivery schedules, and safety level. Medical items have a more conservative stockage objective policy than nonmedical items. The stockage objectives are much lower for medical items to insure that critical medical supplies are still in usable condition when needed.

2.502 Limit Safety Level Quantity

The safety level quantity is the quantity of extra stock held to reduce out-of-stock conditions in the event of minor variations in demand or delays in replenishment of stock. Safety level computations in DLA do not consider shelf-life characteristics. Safety level quantities for shelf-life items can be quite high, ranging from 0 to over 8 million units. Reducing safety levels reduces both the stockage objective and the reorder point. Placing a cap on safety levels helps to prevent excessively high stockage levels and disposal costs, but tends to increase the chance of backorders.

We evaluated limiting safety level quantities to one month of forecasted demand for alternative S1 and three months for alternative S3. As alternative S%, we limited safety level quantities to 10 percent of their shelf-life months times their forecasted monthly demand for nonextendable items and 20 percent of their shelf-life months times their forecasted monthly demand for extendable items. We gave extendable items a higher safety level because their shelf-life can be periodically extended if they pass an inspection; whereas, nonextendable items are disposed when shelf-life is expired.

2.503 Limit Returns

In alternative R, the model reduced returns by not accepting returns on items which were already overstocked. In the current system the returnable limit is a predetermined requirements level used as a criterion for acceptance or rejection of customer reported excess. When DLA stocks exceed the returnable limit, DLA no longer accepts returns. Currently the returnable limit is the total of 16 quarters of forecasted demand plus war reserve requirements plus any additional retention quantities deemed necessary by the item manager. This limit, however, may not exceed the item's forecasted demand over its entire shelf-life period. It is calculated as follows:

$$\text{LIMIT} = \text{minimum of } (16*\text{QFD})+\text{OWRMR}+\text{ARQ} \text{ or } \text{MFD}*\text{SHM}$$

where LIMIT = the retention limit
OWRMR= other war reserve material requirements
ARQ = additonal retention quantity
QFD = quarterly forecasted demand
MFD = monthly forecasted demand quantity
SHM = shelf-life months

Our proposed alternative maintains the same basic formula, 16 quarters of demand plus war reserve plus additional requirement quantities. However, the returns limit in our alternative may not exceed the item's maximum stockage objective. The maximum stockage objective is the maximum buy up to stockage level allowed. It is based on the item's shelf-life and forecasted demand. It currently limits the buy quantity to prevent overstocking, but in this alternative, it will also limit returns.

2.504 Make Smaller More Frequent Buys

In alternative B3 we simulated buying only three months worth of demand for hazardous shelf-life items. Currently the procurement cycle or time between buys, for hazardous shelf-life items ranges from three months to three years. By making more frequent and smaller buys, we should have fresher stock and could better adjust our buy quantities to changing patterns of demand.

2.505 Schedule Smaller, More Frequent Deliveries

In alternative D3 we modeled scheduling replenishment deliveries to the depots every three months. In this alternative, DLA maintains the regulations that upon receipt the stock must have at least 85 percent of its shelf-life remaining.

2.506 Deliver Stock Directly From Vendor To Customer

Alternative DD allows stock to be delivered directly from the vendor to the customer if the requisition is above the minimum direct delivery order size. The advantage of this alternative is that DLA should be able to reduce their receiving, inspecting, holding, disposing, and issuing costs because only requisitions below the minimum direct delivery quantity need to be shipped from the DLA depots. Additional advantages are that lead times are reduced, the customer receives fresher stock, and ordering costs are reduced.

Although the simulation models direct deliveries for all items in this alternative, direct delivery is not currently available for all DLA stocks. Generally only items with commercial applications are currently available for this alternative. These items require specialized Indefinite Delivery Type Contracts. These contracts generally establish a long term relationship between the government and the vendor which allows stocks to be cheaply reordered on an as needed basis. When the government and vendors can establish automated electronic transfer of orders with direct deliveries, as was done in the Paperless Ordering Placement System, costs are reduced even further. The simulation modeled direct delivery of all stocks to determine if direct delivery is advantageous and should be encouraged when possible.

2.507 Reduce The Economic Order Quantity (EOQ)

The EOQ is a computed figure determining the buy quantity. The EOQ used in the current system is too high for shelf-life items because deterioration costs are not considered in the computation.

We tested two alternative ways of reducing EOQ. In alternative ED, we included disposal costs in the EOQ. By failing to include these costs, the current system tends to overestimate the EOQ. In alternative ES we limited the EOQ so that it could not exceed the stockage objective. Both alternatives ED and ES tended to reduce the EOQ. Alternative ED, however, tends to reduce the EOQ slightly for all items, while alternative ES reduces EOQ only when the EOQ is excessive.

2.508 Establish A Minimum Buy Quantity

We forced the system to buy at least one quarter's worth of stock on each buy. In the current system the stockage objective is restrained by the shelf-life of the item whereas the reorder point does not consider shelf-life. In certain cases a high reorder point combined with a low stockage objective may force the system to make small frequent buys. This causes excessive buying and receiving costs. Although the current system has a minimum buy quantity, it must be set manually by the item manager and is rarely used. Over 91 percent of the items in our sample had a minimum buy quantity of zero. In alternative MB, we established the quarterly forecasted demand as the minimum buy quantity for all items.

2.509 Recalculate The Reorder Point And The Stockage Objective

We tested two alternative ways of recalculating reorder points and stockage objectives. As mentioned earlier, the current stockage objective is limited by the item's shelf-life, whereas the reorder point does not consider shelf-life. Buying and receiving costs increase when the reorder point is too high or the stockage objective is too low.

In alternative RS, if the reorder point equals or exceeds the stockage objective, the reorder point is reduced to half of the stockage objective. However, the new reorder point must equal or exceed the forecasted demand over the lead time. If the stockage objective still does not exceed the new reorder point, the stockage objective is set to the reorder point plus one quarter of forecasted demand.

For alternative SR, if the stockage objective minus the reorder point is less than the quarterly forecasted demand, then both the reorder point and the stockage objective are recalculated. In this alternative, the new reorder point is the forecasted demand over the lead plus half of the safety level. The new stockage objective equals the new reorder point plus the forecasted demand over the procurement cycle. The new stockage objective must be less than the demand over the shelf-life.

In both alternatives we are trying to increase the buy quantity by reducing the reorder point and increasing the stockage objective. However, we are attempting to keep the reorder point high enough to avoid backorders and the stockage objective low enough to avoid overstockage and disposals.

2.510 Combine Alternatives

We also tested combinations of the above alternatives. Many combinations were tested, but for brevity, only the results for more promising combination alternatives are displayed in this paper.

3. RESULTS

3.1 The Shelf-Life Simulation Was Statistically Validated

We validated the Shelf-Life Simulation by comparing the simulation results for five replications to actual data (see Table 1). In all cases, the actual data average fell within the 95 percent confidence interval of the simulation average.

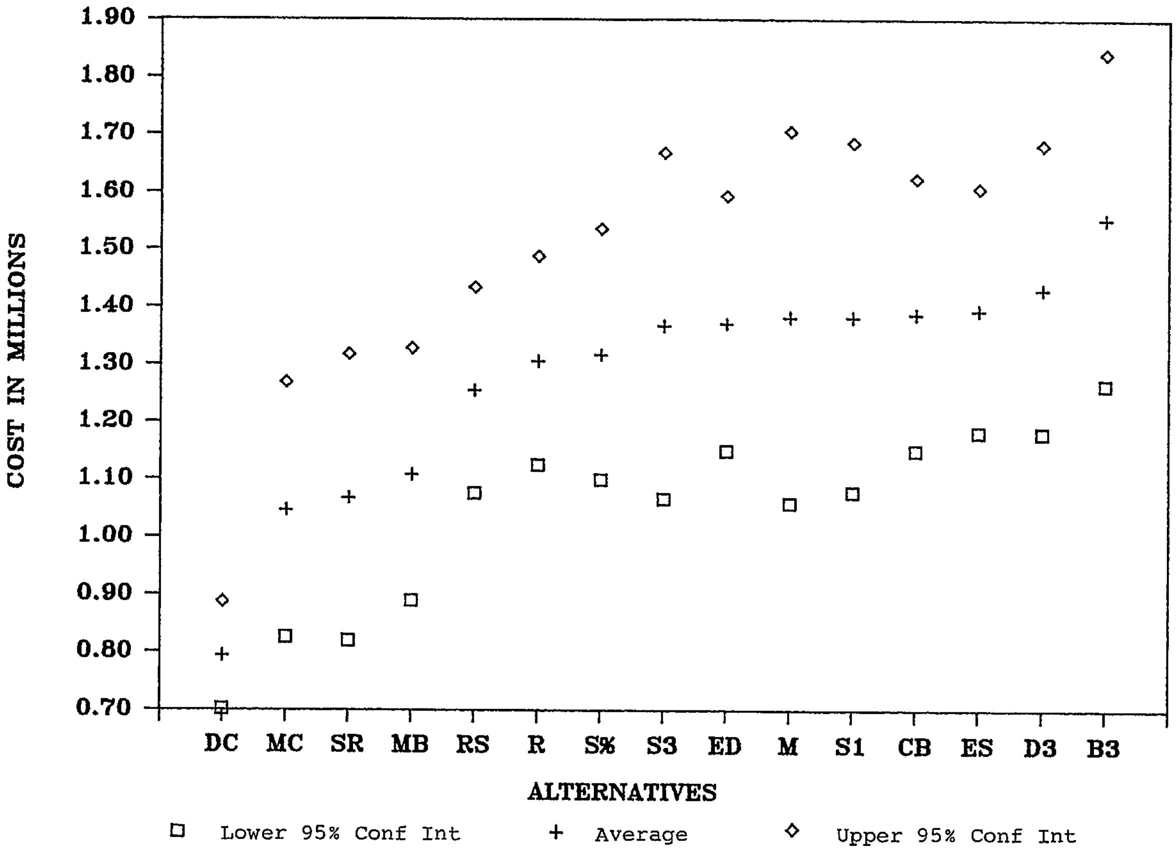
3.2 Comparison Of Alternatives

The direct delivery combination (DC) alternative had a significantly ($P<.005$) lower cost (See Figure 1) than current baseline (CB) system. The direct delivery combination alternative also had a high supply availability (See Figure 2), but this difference was not significant at the .05 probability level. In the direct delivery combination alternative we stipulated that direct deliveries would not be split. We also combined the direct deliveries with alternative SR to control the reorder point and stockage objective.

TABLE 1: Shelf-Life Simulation Validation

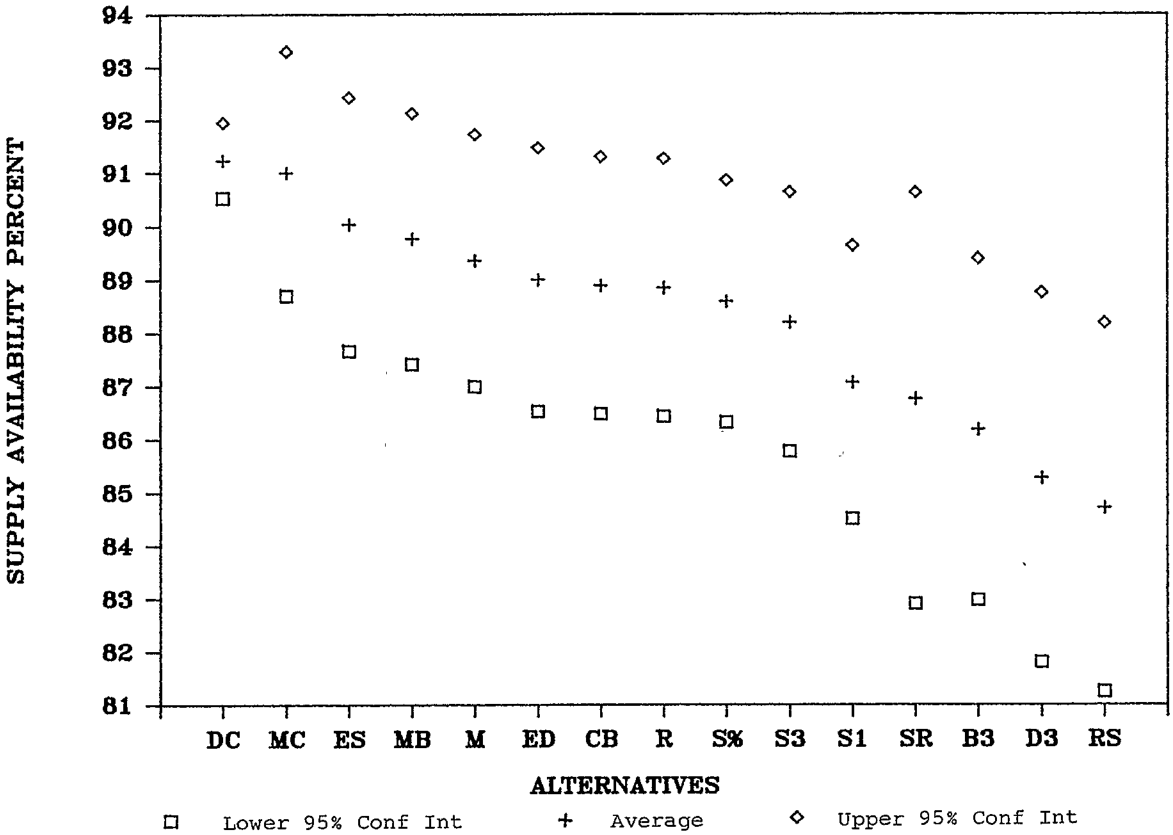
	Actual Value	Simulation Average	Simulation Standard Deviation	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Disposal Dollars (In Millions)	3.40	4.68	5.11	1.51	7.85
Demand Dollars (In Millions)	780.61	795.58	33.90	774.57	816.59
Demand Frequency (In Millions)	1.33	1.33	0.03	1.31	1.35
Supply Availability Percent	91.51	91.37	1.87	90.21	92.53

When direct delivery is implemented several problems emerge because of the radical decrease in demands filled by the depot. Excess stocks must be issued from the depot before direct delivery is started. Demand forecasts, economic order quantities, safety levels, reorder points, and stockage objectives respond slowly to the sudden decrease in demand when direct delivery is implemented. Therefore, we needed to make adjustments to the reorder point and stockage objective to prevent small frequent buys and receipts. Although we modeled direct delivery for all items, direct delivery is not available for all items. We have demonstrated that direct delivery is advantageous when possible.



B3 - Maximum buy is three months of forecasted demand
CB - Current baseline
D3 - Maximum delivery is three months of forecasted demand
DC - Direct delivery combination
ED - Include disposal costs in economic order quantity
ES - Cap economic order quantity by the stockage objective
M - Apply conservative medical stockage objectives to DLA
MB - Minimum buy is three months forecasted demand
MC - Minimum buy combination
R - Don't accept returns if over the stockage objective
RS - Recalculate reorder point and stockage objective if stockage objective < reorder point
S1 - Limit safety level to one month of forecasted demand
S3 - Limit safety level to three months of forecasted demand
SR - Recalculate reorder point and stockage objective if stockage objective - reorder point < three months demand
S% - Limit safety level to a percentage of the item's shelf-life

Figure 1: The Direct Delivery Combination Alternative Had The Lowest Cost



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S% - Limit safety level to a percentage of the item's shelf-life

Figure 2: The Direct Delivery Combination Alternative Had The Highest Supply Availability

When direct delivery is not possible, establishing an automated minimum buy quantity to prevent small frequent buys and deliveries was a good alternative. The minimum buy quantity, however, must be low enough not to significantly increase holding costs, reinspecting costs, and disposing costs. We found that a minimum order quantity of forecasted demand for one quarter was effective. Eliminating small buys also increased supply availability. Small frequent buying saves on holding costs but does not maintain a sufficient buffer against erratic demand patterns.

The minimum buy alternative was particularly effective when combined with the alternatives which cap the EOQ, use the medical stockage objective, and do not accept returns when over the stockage objective (Alternatives ES, M, and R). The minimum buy combination alternative (MC) had high supply availability.

The alternatives limiting safety level did not perform well. They decreased supply availability and increased buying and receiving costs. The alternatives setting caps on delivery and buy quantities also did not perform well because they increased the number of small buys and receipts. The alternatives which recalculated the reorder points and stockage objectives tended to save money but hurt supply availability due to the decreases in the reorder point. The more conservative stockage objective both reduced costs and backorders. Capping the economic order quantity by the stockage objective also reduced backorders. However, the general increase in economic order quantity produced by alternative ED had little effect. Not accepting returns when overstocked reduced return disposal costs and returns receiving cost but had no effect on supply availability.

4. CONCLUSIONS

The direct delivery with adjustments to reorder point and stockage level was the best alternative for both cost and supply effectiveness. When direct delivery is not possible, establishing a minimum buy quantity with the more conservative stockage objective and limits on EOQ and returns is the next best alternative. The forecasted demand over one quarter appeared to be a good minimum buy quantity.

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