Logistics Management Institute

# Economic Retention of Ammunition Items

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Dennis Zimmerman



LMI

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# Executive Summary

When stock levels in the DoD supply system exceed those needed to sustain normal operations, materiel managers need to decide whether it is cost-effective to retain that stock or dispose of it. Economic retention models support that decision-making by trading off the savings from disposal against the savings from retention to arrive at a breakeven point. That point is an item's economic retention limit.

The military force drawdown in response to the collapse of the Soviet Union, the introduction of new items, and a lack of funds to accomplish demilitarization and disposal of unusable ammunition stocks have all contributed to a growth in the DoD ammunition stockpile. To help resize the stockpile to meet the needs of today's and tomorrow's military forces, the Joint Ordnance Commanders Group established the Ammunition Management Improvement Coordinating Committee (AMICC). Working with the AMICC, the Office of the Assistant Deputy Under Secretary of Defense for Materiel and Distribution Management tasked the Logistics Management Institute to study how the department should set economic retention levels for ammunition items.

We started our analysis by identifying the factors that should be considered in an economic retention model for ammunition items. We examined ammunition materiel management policies and procedures that focus on storage, disposal, and procurement—the three areas normally involved in economic retention. We found that although differences exist in the management of ammunition and nonammunition items, those differences do not affect the factors involved in economic retention. Those factors are forecasts of future demand, storage costs, acquisition costs, and net disposal costs.

Using the standard principles that are applied to the economic retention of nonammunition items, we developed a model that generates economic retention limits for individual ammunition items (and groups of items). The model performs a net present value analysis of the difference between retention and disposal savings. The major difference between this model and a model for nonammunition items is that the expression for return from disposal is negative because the cost of demilitarization exceeds any salvage revenues.

To analyze the economic retention limits that the model would generate, we developed a range of estimated values for cost factors in the model and collected data for a sample of ammunition items. The AMICC assisted us by providing studies and management reports to develop estimates. They also provided data for items from small projectiles to tactical missiles.

We first ran the model with the assumption that demand for an item continues indefinitely. The resulting economic retention limits in almost all cases were more than 50 years and far exceeded the normal service lives for ammunition items. We then ran the model with demand set to occur over a fixed period of time (to simulate service life). The resulting economic retention limits had the fixed period of demand as their minimum. In short, both sets of runs support the retention of a stock level equal to all forecasted future demand.

Although the model dictates economic retention limits that cover all future demand, some probability exists that managers will not be able to forecast future demand exactly. We extended our analysis to address this probability. We applied statistical theory and computed economic retention limits that compensate for forecasting errors with a high degree of confidence. Use of these limits offers a practical and cost-effective solution for determining ammunition economic retention stocks.

Based on our analysis, we concluded the following:

- The factors involved in the economic retention of ammunition items are the same as the factors involved in the economic retention of nonammunition items, although the factors have different values.
- The standard net present value model used to set economic retention limits for nonammunition items can be used for ammunition items by modifying the expression for revenues from disposal.
- Based on our testing, the most economic retention limit for an ammunition item is the level of stock that will cover all known future demand for the item.

Therefore, we recommend the following:

- The economic retention limit for an ammunition item should simply be based on its remaining service life because that limit is the same as the limit generated by an economic retention model.
- The computation of an item's economic retention limit should consider the normal level of error in forecasting future demand and provide a high level of confidence that future customer demand is satisfied.

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# Chapter 1
# Introduction

In materiel management, the term *economic retention limit* refers to the maximum amount of stock that may be economically retained. This report documents the results of a study that the Logistics Management Institute (LMI) conducted for the Office of the Assistant Deputy Under Secretary of Defense for Materiel and Distribution Management (ADUSD[MDM]) on economic retention limits for ammunition items. This chapter reviews the background, scope, findings, conclusions, and recommendations of the study.

## BACKGROUND

Since the end of the Cold War, ammunition requirements have declined and stock returned from field activities has caused the DoD stockpile to grow. This situation is acerbated by modernization initiatives that are introducing new, more effective items requiring less inventory than the items they are replacing.

For nonammunition secondary items, such as repair parts, the Department of Defense has historically used economic retention limits (e.g., 10 years of stock) to decide how much stock should be retained above an item's normal operating levels. Item managers use economic retention limits as follows:

- The on-hand stock level of an item is compared to the item's economic retention limit.
- If the on-hand level is less than or equal to the limit, no further processing is required.
- If the on-hand level is greater than the limit, then the portion of stock above the limit enters into consideration for contingency retention or potential disposal.

Although the military services also have retention limits for ammunition items, item managers tend to retain and not dispose of ammunition stocks. Like item managers for nonammunition items, ammunition item managers retain stock to guard against the normal uncertainties associated with future demand for their items. This action is reinforced by the fact that disposal of ammunition items requires demilitarization, and demilitarization costs typically exceed any salvage revenue.

To ensure that the department is applying sound economic decision-making in the area of ammunition retention, ADUSD(MDM) tasked LMI to study how the department should set economic retention levels for ammunition items.

## SCOPE

The Department of Defense has an ongoing initiative to resize its ammunition stockpile to meet the needs of today's and tomorrow's military forces. ADUSD(MDM) has been working with an interservice committee on issues related to reducing the ammunition stockpile. That committee, the Ammunition Management Improvement Coordinating Committee (AMICC), has addressed several major issues, including ammunition transfers by the military services instead of new procurements. The committee requested analytic support in the area of economic retention because current limits are not based on precise economic models.

## APPROACH

To provide the requested support, we

- identified the factors that should be considered in an economic retention model for ammunition;
- formulated a model that generates economic retention limits for individual ammunition items and groups of items;
- developed estimates of costs and other factors in the model and, with a sample set of items, ran the model
  - initially with an *infinite horizon*, that is, with the standard assumption applied in retention modeling that demand for an item continues indefinitely,
  - next with a *fixed horizon*, that is, with the assumption that demand for an item ends at some known point in time; and
- examined how the statistical theory of confidence could be used to set retention limits that represent low-cost solutions to the problem of how much stock is needed to satisfy future demand over fixed horizons when demand varies.

# CONCLUSIONS

*The factors involved in the economic retention of ammunition items are the same as the factors involved in the economic retention of nonammunition items, although the factors have different values.*

We started our study by reviewing the ammunition supply business through a reading of the literature and interviews with subject matter experts. We found that although inventory management policies and procedures are slightly different for ammunition items than for other items in the DoD supply system, the factors and computations involved in economic retention are the same for both sets of items. We also concluded that the ammunition values for those factors are different from the values for other items, primarily in the case of disposal where salvage revenues are negative.

*The standard net present value model used to set economic retention limits for nonammunition items can be used for ammunition items by modifying the expression for revenues from disposal.*

We developed a model using government-wide principles for conducting economic analyses of alternatives spanning 3 or more years. The resulting net present value model computes economic retention limits by trading off disposal savings against retention savings. It differs from the standard net present value model used for other items in the mathematical expression for salvage revenues. That expression is negative because demilitarization costs exceed salvage revenues.

*Based on our application of the model, the most economic retention limit for an ammunition item is the level of stock that will cover all known future demand for the item.*

Our model runs revealed the following:

- The *infinite horizon* runs verified that the model behaved as expected. However, the economic retention limits set by the model were in almost every case more than twice the service lives of ammunition items. Sensitivity testing showed some minor sensitivity to the cost of storage, less to the cost of disposal, and none to the cost of procurement.

- The *fixed horizon* runs revealed that the minimum limit should be the period of time that the item is expected to be in service even if demand is expected to decline.

Both sets of runs point to limits that cover all future forecasted demand. However, demand forecasting is not an exact science, and some error is expected. To account for demand variability and forecasting errors, we developed statistical levels that provide for a high level of confidence that customer demand will be satisfied throughout the target horizon. These levels offer a practical solution for computing economic retention limits for ammunition items.

## RECOMMENDATIONS

Based on our analysis, we recommend the following:

- Economic retention limits for an ammunition item should simply be based on its remaining service life. That service life should be no greater than the life of the using weapon system. If an item is not associated with a single weapon system, the limit should be based on a maximum period of planned usage.
- The computation of limits should consider the normal level of error in predicting future demand and provide a high level of confidence that customer demand will be satisfied throughout the target horizon.

## REPORT ORGANIZATION

The remainder of the report is organized as follows:

- Chapter 2 reports on our investigation of the factors that need to be considered in the economic retention of ammunition items.
- Chapter 3 describes our development of an ammunition economic retention model.
- Chapter 4 describes our development of estimated values for factors in the model, the sample set of items we used for running the model, and the results of the model runs.
- Chapter 5 describes how to compute the statistical limits that we recommend.

Chapter 2

# Economic Retention and Ammunition Materiel Management

Because military ammunition items are not available for issue from commercial distributors but are batch manufactured in lots for strictly military use, the defense department needs to stock and store them for when they are needed. However, their hazardous and lethal nature and intended use make their management different from other items in the DoD supply system. In this chapter, we examine how those differences affect decisions to retain or dispose of stock. However, before we discuss ammunition materiel management, we briefly discuss what economic retention is and its role in materiel management.

## WHAT IS ECONOMIC RETENTION

*Economic retention* is the retention of stock solely on the basis of cost-effectiveness. Economic retention is not the retention of stock to meet potential contingencies; that is contingency retention.

An economic retention limit is the stock level that represents the breakeven point between the costs of retaining and disposing of stock. It should vary by item because the costs of retaining or disposing of stock will vary by item. It is neither a level of stock that an item manager must have on hand nor a level that is procured or considered in procurement. It only plays a role in materiel management when stock levels are excess to those normally kept to supply customers.

## WHY ECONOMIC RETENTION

As a steward of public funds, the defense department should always seek to apply financially sound policies and procedures when expending those funds. In this case, such policies and procedures are needed to deal with the costs associated with the excess stocks that result from higher-than-needed procurements, lower-than-expected demand, and unexpected customer returns.

Within the defense department, inventory management must respond to demand for many items from customers throughout the world. Unlike the demand that supports domestic production, the demand that supports military operations is constantly changing and difficult to forecast. Often, expected future demand either does not materialize or is overtaken by actual demand. Actual demand can also be lower than expected when a new item is introduced and the old item is being phased out faster than planned. When stocks are drawn from inventory at a lower rate than forecasted, supplies start to accumulate above levels normally kept to support customer requirements.

Stock levels can also climb when customers return materiel faster than they are drawing it out of inventory. Decisions to close bases and to return deployed forces causes the stocks at those bases or with those forces to be returned to the supply system. In particular, the massive returns from Europe after the Cold War and from the Near East after Operation Desert Storm contributed to growth in the ammunition stockpile and its storage space requirements.

When stock levels climb above planned levels, the department needs to answer the question, "How much is too much?" To answer this question, the department has traditionally relied on economic retention limits. These limits are set by computing and comparing the cost of retaining stock against the cost of stock disposal and potential reprocurement in an economic retention model.

The level-setting process starts by looking at the costs of retaining increasing numbers of years of stock. It stops when the cost of retaining stock for a given number of years exceeds the cost of disposing of that stock and then potentially later having to procure it again. The economic retention limit is set equal to the last year that the cost for retaining stock for an item is less than the cost for disposing of it. For repair parts managed by the department, economic retention limits have historically ranged between 5 and 20 years.

## Materiel Management and Ammunition

Today, the Defense Logistics Agency is the DoD wholesale manager for most consumable and field-level reparable items while the military services are wholesale managers for depot-level reparable items. Depot-level reparable items that are used by more than one military service have one service designated as the principal inventory control activity (PICA) while the other services act as secondary inventory control activities (SICAs). A SICA determines the requirements that its respective service has for the common-use item and provides those requirements to the PICA. Besides acting as a SICA for its service, the PICA directs the overall DoD procurement and repair programs that support the requirements from all using military services.

Prior to FY77, each military service managed all of its own munitions during peacetime. To eliminate duplication and fulfill wartime tasking more efficiently, inventory management of conventional ammunition items was centralized under a single manager for conventional ammunition (SMCA). Under this centralization, the services only retain management of selective munitions. The relationship between the SMCA and the services is similar to the PICA–SICA arrangement for common-use reparable items.

## Single Manager for Conventional Ammunition

DoD Directive 5160.65, "Single Manager for Conventional Ammunition (SMCA)," last reissued on 8 March 1995, assigns the SMCA mission to the Army. It lists the objectives of the SMCA mission and assigns general responsibilities to the Under Secretary of Defense for Acquisition and Technology, the DoD Comptroller, the Secretary of the Army, and the secretaries of the other military departments.

DoD Instruction 5160.68, "Single Manager for Conventional Ammunition (SMCA): Responsibilities of the SMCA and the Military Services, 3 March 1995, implements DoD Directive 5160.65 by specifying the functional responsibilities and mission functions to be performed by the SMCA and by the military services. The following principal functions pertain to this study and are performed by the SMCA:

- Acquisition of ammunition
- Wholesale storage and custodial accountability
- Maintenance, renovation, demilitarization, and disposal of wholesale assets.

The principal function performed by the military services pertaining to this study is the determination of peacetime and time-phased replenishment requirements given to the SMCA.

## Military Service Management

Enclosure 1 of DoD Directive 5160.65 delineates ammunition items are managed by the SMCA and items managed by the military services. The separation of management is not relevant to this study as it does not change the key processes that have to be considered in an economic retention model.

# Computation of Requirements and Acquisition

The military services are responsible for the determination of peacetime and wartime requirements for ammunition items that they use. Peacetime requirements reflect munitions needs for training of forces and for testing weapon systems. Wartime requirements are developed to equip forces and support combat operations in designated war scenarios. For conventional ammunition, the military services communicate these stockage and corresponding replenishment requirements to the SMCA. The SMCA is responsible for the acquisition of the items to satisfy these requirements.

This division of responsibilities is similar to the PICA–SICA management of reparable items in that users provide their requirements to a central activity for procurement. It presents no barriers to retention decision-making.

## Retention Stock

Normally, wholesale item managers for secondary items only maintain the stock levels they need to support their customers' requirements. However, sometimes after stocks are acquired, customer requirements decline or customers return materiel to the supply system. This situation results in stock levels that are above normal peacetime operating levels.

This same situation occurs with ammunition items. Over recent years, national defense strategies have led to decreases in peacetime and wartime ammunition requirements. Moreover, since the end of the Cold War, the downsizing of forces and closure of bases has caused stock returns to be particularly high for ammunition items. Like other wholesale managers, ammunition managers are now faced with stock levels that are excess to those levels that they would normally maintain to support operations. They need to

- retain the excess stock as retention stock (i.e., stock held for issue but not for reprocurement)
- make it available to another service through cross leveling or
- dispose of it.

Currently, DoD Regulation 4140.1-R, "DoD Materiel Management Regulation," January 1993, addresses economic and contingency retention of principal and secondary items but provides no specific guidance for munitions. It states that economic retention should be based on an economic analysis of retaining or disposing of stock while contingency retention should be based on a specific national defense purpose. The regulation also states that wholesale item inventories retained to support weapon systems shall be reduced in proportion to any reduction in the number of systems in use.

The AMICC is tailoring DoD 4140.1-R retention policies and procedures to provide for the economic and contingency retention of munitions stocks. To warrant economic retention, an ammunition item must have long-term peacetime requirements.

## Substitution

As with many categories of items, munitions can be upgraded. In his speech at the American Defense Preparedness Association Munitions Executive Summit on 17 September 1996, the Under Secretary of Defense for Acquisition and

Technology listed "revolutionary modernization and modular improvements to existing items" as the first and second components of DoD's seven-part munitions program. In both cases, one or more munitions items are being modified or replaced with a new item that will be more effective in future battlefields.

Replacing an item raises the question of what to do with the stocks for that item. Normally, the new item is the preferred item that forces want to train with in peacetime and fight with in wartime. However, the military services can often use an old item as a substitute item; that is, they can use it to offset a portion of training requirements and to satisfy wartime requirements for the preferred item. When an old item is used to satisfy wartime requirements, the substitution usually is greater than one for one because the newer item is more effective.

A substitute item is not like an obsolete item in that it may have some future peacetime training usage or war reserve application. If it does have some future training usage, it should qualify for economic retention. If it does not and only has a war reserve application, it qualifies for contingency retention and not for economic retention.

# Storage and Maintenance

The SMCA manages wholesale storage and maintenance ammunition and explosives depots for all the military services. From these depots, stock is issued to retail storage points such as camps, posts, forts, and bases. The same depots also receive serviceable and unserviceable returns from retail storage points.

At SMCA depots, ammunition stocks are either in covered storage areas or open areas. Covered storage is preferred because it provides protection against the elements that can corrode or otherwise deteriorate ammunition stocks. Although deterioration can occur over time in covered storage, outside storage can speed the process and increase the funding required to restore items to a usable condition. Ammunition stocks that are awaiting disposal are often stored outside to free covered storage space for new stocks entering the depots.

However, storage space shortages have caused some usable ammunition to be stored outside when it should be stored inside. Those shortages are the result of downsizing, the addition of ammunition from Europe and Operation Desert Storm, the retention of ammunition that is unusable or awaiting disposal, and the proliferation of fragmented (broken up) lots of ammunition. When materiel is stored outside, it must be restored to a usable condition before it can be issued. Insufficient inside storage would result in outside storage that, in turn, would add restoration costs to the cost of storage. Since the cost of storage is a factor in setting economic retention limits, this situation could affect those limits.

## DISPOSAL

Stock that is excess to all defense requirements is normally disposed of after it undergoes screening by other federal, state, or local activities for possible reutilization. The same is true of ammunition that is excess to the needs of a particular service except that reutilization screening is limited to within the military services.

Normally, disposal produces some salvage revenue. However, in the case of ammunition, the disposal process involves demilitarization; that is, the destruction of the lethal capability of ammunition through burning, exploding, or other means to prevent its further use for its originally intended military purpose. Besides the cost of demilitarization itself, the demilitarization process involves other costs, such as depot costs to store stock awaiting demilitarization and transportation costs to move the stock to a demilitarization site. In short, demilitarization takes time and money, and afterwards little or no materiel remains for salvage. Consequently, although disposal is a factor in ammunition retention, as it is for any class of items, salvage revenues would be negative rather than positive.

## SUMMARY

The division of wholesale management responsibilities, the methods used to compute operating and replenishment requirements, and the procedure for disposal of stock make inventory management slightly different for ammunition items than for other items in the DoD supply system. However, these differences do not affect the need for retention decision-making or change the factors involved in that decision-making.

However, the differences do affect the values of factors involved in retention. Normally, those values will differ slightly by type of item or by managing organization. However, in the case of disposal savings, the difference between ammunition items and nonammunition items is significant as salvage revenues are not positive for ammunition items. As explained in chapters 3 and 4, respectively, this difference is important in building a prototype retention model for ammunition items and producing the results with estimated values for the model's factors.

# Chapter 3
# Developing an Economic Retention Model

As we discussed in chapter 2, economic retention models that trade off the savings from disposal against savings from retention are at the heart of deciding how much stock should be retained. Using economic principles, such as discounting and net present value, a model can be developed to make this tradeoff for ammunition items and to set their economic retention limits. This chapter examines the economic principles used to set limits, the savings that are involved in disposing or retaining stock, and the mathematical development of an economic retention model for ammunition.

## PRINCIPLES BEHIND ECONOMIC RETENTION

Office of Management and Budget (OMB) Circular No. A-94, *Guideline and Discount Rates for Benefit-Cost Analysis of Federal Programs,* 29 October 1992, presents guidelines and discount rates for benefit-cost analysis of federal programs. It provides general guidance on conducting cost-effectiveness analyses and specific guidance on the discount rates to be used in evaluating federal programs whose benefits and costs are distributed over time.

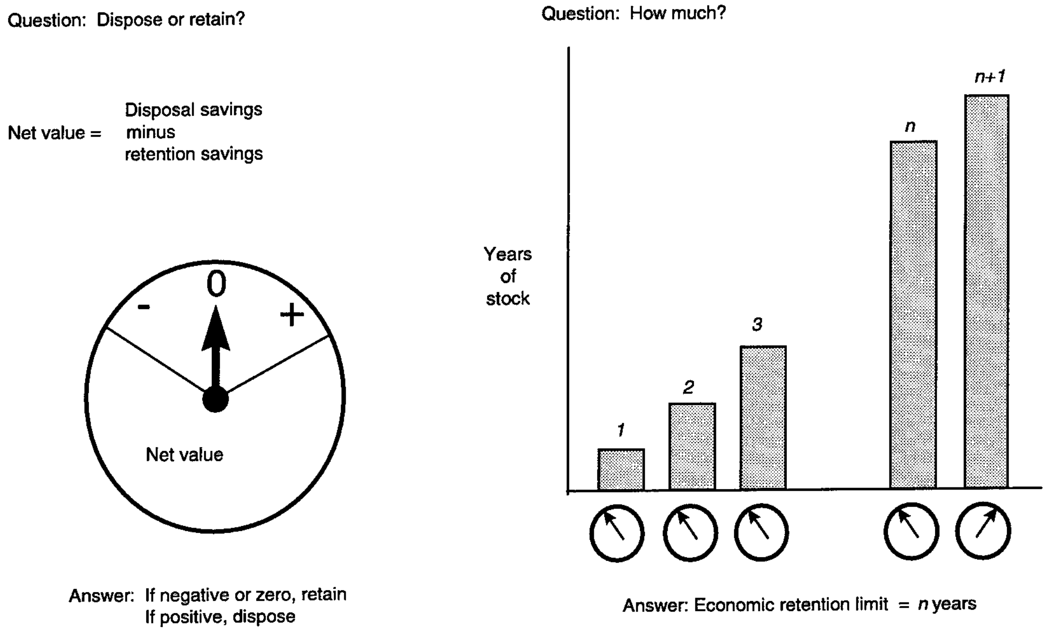
The economic retention program involves two alternatives—retain stock for demand in a given future year or dispose of it. Since each of the two alternatives have measurable costs that extend for 3 or more years in the future, the principles of cost-effectiveness analysis presented in OMB Circular No. A-94 apply. Those principles state, "A program is cost-effective if, on the basis of life-cycle cost analysis of competing alternatives, it is determined to have the lowest costs expressed in present value terms for a given amount of benefits."

In this case, we consider providing the same benefits for the same number of years in the life cycle of an item. Therefore, to determine the number of years it is cost-effective to retain stock, we need to

- examine the net savings between the two competing alternatives (i.e., the difference between the savings from retaining stock and the savings from not retaining or disposing of stock),
- use discount factors to express those net savings in present value terms, and
- stop at the year when the discounted net savings are negative.

Figure 3-1 illustrates this process.

*Figure 3-1. Basic Questions and Answers of Economic Retention*




# Disposal Savings

The savings from disposing of stock are twofold—savings in storage costs and revenues from disposal. If we retain stock to fill demand in future year *n*, we incur the annual costs of storing that stock for $n-1$ years. If we decide not to retain that stock, we do not incur those costs. In the case of ammunition, those costs involve the cost of warehousing the stock in a secure and covered area and the cost of performing maintenance to prevent deterioration. Normally, by disposing of the stock, we gain the immediate benefit of any salvage revenues. However, in the case of ammunition, the disposal process involves demilitarization and, as we discussed in chapter 2, demilitarization causes disposal revenues to be negative.

# Retention Savings

The savings from retaining stock revolve around the avoidance of future reprocurement costs. By not disposing of the stock we already procured and have on hand for some future year *n*, we avoid the costs of having to procure the stock for a second time so that we have it available to satisfy demand in that year. Those costs are the administrative or ordering costs associated with making a procurement and the purchase price of the material itself. Our savings would, therefore, be the sum of these two costs.

(In actuality, if no demand occurs in year *n* or the demand for previous years is lower than expected and stock is carried over to fill demand in year *n*, then no reprocurement costs and no cost avoidance occur. Or, to a lesser extent, if the demand for year *n* is lower than expected or some stock carryover fills a portion of the demand in year *n*, then savings would be less than expected. These possibilities point to the importance of having the best possible forecasts of future demand and giving consideration to demand variance when computing savings.)

# FORMULATING A MODEL

The formulation of any economic analysis model depends on how savings are to be treated and how alternatives are to be compared. The following two considerations are central to the treatment of savings:

- Are future savings in terms of real or constant-dollars (i.e., in units of stable purchasing power) or nominal terms (i.e., in terms of future purchasing power of the dollar)?
- Are savings to be discounted? (*Discounting* is the technique to reflect the time value of money; that is, savings are worth more if they are experienced sooner.)

In this case, since savings extend past 3 years, OMB Circular No. A-94 calls for discounting to be applied to arrive at the net present value of disposing of or retaining excess stock. It also states that a real discount rate can be approximated by subtracting expected inflation from a nominal interest rate.

As for the comparison of alternatives, a retention model must trade off the savings of retaining stock, one alternative, against the savings of not retaining stock, the other alternative. This tradeoff can be accomplished by

- a comparison of total savings of the two alternatives,
- an evaluation of the differential savings between the two, or
- a comparison of the alternatives' rates of change in savings.

All three forms will yield the same answer. However, the first two forms are mathematically simpler than the third. Because the second form omits costs that are the same for both alternatives, it involves fewer and easier computations than the first. Therefore, it has the advantages of both simplicity and ease in computation.

# Building the Mathematical Model

Based on the previous discussion, we selected the net present value model for our ammunition retention model. It is a difference equation consisting of mathematical expressions for the savings from disposing of stocks for an ammunition item and the savings from retaining those stocks. Mathematically, it is

$NPV(n) = DS(n) – RS(n)$, [Eq. 3-1]

where

$n$ = the year of stock being considered for retention,

$NPV(n)$ = the net present value of the difference in savings between disposing of stock for future year $n$ and retaining that stock,

$DS(n)$ = savings from disposing of stock for future year $n$,

$RS(n)$ = savings from retaining stock for future year $n$.

(Throughout this discussion, when we use the term "stock for future year $n$," we mean the amount of stock equal to the expected demand for an item in future year $n$.)

As previously illustrated in Figure 3-1, the retention-disposal decision is an iterative process. For each year that $NPV(n)$ is negative for some year $n$, the savings from retaining stock exceed the savings from disposing of it, and the decision is to retain the stock. However, as the year $n$ increases, if the difference becomes positive for some year $n$, then the savings from disposal outweigh the savings from retention, and the decision is to retain $n–1$ years of stock and dispose of all stocks above that level.

## Expressions for Savings from Disposing of Ammunition Stock

The savings from disposal are the savings from not storing the stock and the salvage revenues. Mathematically, it is

$DS(n) = SS(n) + SR$, [Eq. 3-2]

where,

$n$ and $DS(n)$ are as previously defined,

$SS(n)$ = accumulated storage savings from not storing stock for future year $n$; that is, the sum of storage costs for years 1 through $n–1$,

$SR$ = the immediate salvage revenues from disposing of a year of stock (this expression is independent of $n$ since we assume that the annual training requirement remains constant in future years).[1]

Storage savings consist of a single expression reflecting the costs for storing the given year of stock until it is used. That expression is as follows:

$SS(n) = \Sigma(f_i)(d)(s),$ [Eq. 3-3]

where

$n$ and $SS(n)$ are as previously defined,

$\Sigma$ = the summation of terms from $i = 1$ to $i = n-1$,

$f_i$ = the discount factor for year $i$,

$d$ = the annual training requirement (i.e., the annual demand for the item),

$s$ = the annual cost to store a unit of the item.

Salvage revenues (or net savings from disposal) also consist of a single expression reflecting the costs of demilitarizing a year of stock. That expression is as follows:

$SR = -(d)(m),$ [Eq. 3-4]

where

$SR$ and $d$ are as previously defined,

$m$ = the cost to demilitarize and dispose of a unit of the item.

## Expressions for Retaining Ammunition

As previously discussed, the savings from retaining stock are a cost avoidance, namely, the avoidance of reprocurement costs. Those savings can be put in one expression that encompasses the savings in materiel purchase costs and the savings in the administrative costs to reorder an item. Mathematically, it is

$RS(n) = (f_n)[(d)(u) + P],$ [Eq. 3-5]

where

$n$, $RS(n)$, $f_n$, and $d$ are as previously defined,

[1] In our testing of the model, we disregarded the assumption of constant demand and tested situations where demand changes.

$u$ = unit price for item,

$P$ = the administrative cost of procuring an item.

# SUMMARY

Using the economic principles stated in OMB Circular No. A-94, we were able to construct an economic analysis model that trades off disposal savings against retention savings to compute an economic retention limit for ammunition items. The model itself is a net present value model and is mathematically given as

$$NPV(n) = \Sigma(f_i)(d)(s)-(d)(m)-(f_n)[(d)(u) + P], \quad \text{[Eq. 3-6]}$$

where the variables are as previously defined.

This same model could be used for any item except for the negative sign in front of the expression for salvage revenues (second term on right side of equation). The negative sign denotes the fact that demilitarization causes the ammunition disposal process to cost more than it brings in.

Chapter 4

# Evaluating the Use of an Economic Model

Our formulation of an economic analysis model in Chapter 3 assumes that demand for the item will continue in the future forever. Although this assumption is standard in retention modeling, in reality, the need for an item ends when it becomes obsolete or when age and long-term storage render it unusable.[1] To evaluate the use of a strict cost model for setting ammunition economic retention limits, we compared the economic retention limits from our economic analysis model to fixed limits representing actual item service lives.

This chapter describes how we conducted that comparison by reviewing how we

- estimated values for factors in the economic analysis;
- ran the model in two modes, one with the standard infinite horizon for demand and one with a fixed horizon for demand;
- analyzed the results from both sets of runs; and
- conducted sensitivity analysis of those results.

These analyses served as the basis for our recommendations in chapter 5.

## ESTIMATING VALUES FOR FACTORS IN THE MODEL

In 1996, personnel at the Naval Surface Warfare Center in Crane, Indiana, conducted an ammunition retention analysis. They were able to collect cost data on storage and disposal from the SMCA and conduct tradeoffs between retention and disposal. Although the analysis did not satisfy all of the requirements of OMB circular no. A-94, it did serve as a starting point for estimating values for factors in our model.

### Estimates for Cost of Storage

*Storage cost* is the sum of the annual cost of storing an item and the cost of any maintenance to prevent deterioration while an item is in storage. The cost factor for storing an item is typically given in terms of dollars per square foot (or dollars per ton) of storage occupied so that the annual cost of storing *m* units of an item is *m* times the square footage (or tonnage) per unit times the cost factor. The cost

[1] Obsolescence occurs either when the weapon system using an item is permanently retired from service or when the item is entirely replaced by a new item.

factor for preventative maintenance can also be given in terms of units so that the cost of maintenance for *m* units is *m* times the cost factor.

## Storage Cost Factor

The following typical elements and activities are included in the development of a storage cost factor:

- Utilities (e.g., electricity for lights)
- Inventorying
- Rewarehousing
- Repairs and maintenance of physical facilities.

For its analysis, the Navy collected from the SMCA a cost of $1.94 per square foot for the storage cost factor. The Army provided us with operations and maintenance data on storage tonnage and cost for FY96, FY97, and FY98. That data showed an average storage cost of $12.37, $9.53, and $9.37 per ton, respectively. (Using the rule of thumb that 1 ton is equal to 9 square feet, those averages translate to $1.37, $1.06, and $1.04 per square foot, respectively.)

Although the Army is the manager of ammunition depots, the Defense Logistics Agency (DLA) is the manager for all other distribution depots. DLA's budget for distribution depots reflects an estimated cost of $7.89 per square foot for covered storage in FY98. Given that ammunition storage should have more security and environmental requirements than most items stored in DLA depots, we believe the cost of ammunition storage should be at least as great as the DLA cost of storage. Therefore, we tested our model with both the DLA cost of $7.89 per square foot for covered storage and the Army cost of $9.37 per ton or 4.685 cents per pound for general storage. We also conducted additional analyses to determine the sensitivity of our results to these values.

## Maintenance Cost for Stored Items

Stored ammunition, like other corrosive items, is subject to deterioration and may have maintenance performed to restore them to a usable condition. This maintenance has a cost associated with it. However, we were not able to isolate this cost from other more major maintenance costs associated with ammunition modifications and the restoration of unserviceable units coming from the field. We had to assign a zero to its value, thereby understating the total cost of storing an item. To compensate for this effect, we included in our sensitivity testing a wider spread of percentage increases in storage costs than percentage decreases.

Emphasizing percentage increases also addresses another issue, namely, potential limits on available storage space for ammunition stock. The 1995 Base Realignment and Closure Commission recommended closure of three ammunition storage areas even though, at that time, space utilization was over 80 percent (85 percent is often used as the standard for optimal storage utilization). If the ammunition stockpile were to outgrow the amount of available storage space, then disposal of excesses could no longer be based on costs alone, but would have to consider the physical limits on what could be stored.

To deal with such limits, economic modelers use a *shadow cost*. Shadow costs are artificial costs used in models to force solutions that meet all problem constraints. In this case, the artificial cost would be added to the real cost of storage to drive the retention model toward less storage. The higher the shadow cost is, the lower the total storage requirement would be. Therefore, testing with percentage increases in storage costs is equivalent to testing with a shadow cost for available storage space.

## Disposal Cost Estimates

*Disposal cost* is the sum of the cost to demilitarize an item, the cost of storage awaiting demilitarization, and the cost to transport an item to a demilitarization site, less any salvage return. The cost factor for demilitarizing an item is given in terms of dollars per ton. The cost to demilitarize $m$ units of an item is $m$ times the weight per unit in tons times the cost factor. The cost for storing $m$ units is as previously described except that the cost factor is for outside storage rather than covered storage and its value is practically negligible (DLA's cost for FY98 is $0.05 per square foot). The cost factor for transportation would also be in terms of dollars per ton and, as such, could be added to the cost factor for demilitarizing to arrive at an extended cost factor for demilitarization.

For its analysis, the Navy obtained a value of $1,929 per ton for the cost of disposal, including demilitarization. We obtained demilitarization costs (not including transportation costs) and tonnage from the SMCA for FY94 through FY97. The resulting average cost factors were $888 per ton in FY94, $795 per ton in FY95, $627 per ton in FY96, and $795 per ton in FY97. To be conservative, we used the low average of $627 for our initial testing and later considered higher disposal costs in our sensitivity analysis.

In June 1996, the Joint Ordnance Commanders Group produced the "Munitions Demilitarization Study" that reported average demilitarization costs per ton by the Munition Items Disposition Action System (MIDAS) family. As a second round of testing, we matched our test items with the MIDAS families and used the associated costs.

Salvage return is usually expressed as a percent of the dollar value of the materiel being disposed. For most items, the current salvage return is 2.5 percent. However, an ammunition item undergoes demilitarization as part of its disposal. In most cases, the destruction from demilitarization leaves nothing left for salvage.

Therefore, we assumed a zero percentage and later considered lower disposal costs in our sensitivity analysis.

## Procurement Cost Estimates

As previously discussed, *procurement cost* is the sum of the purchase price of the materiel being procured and the administrative cost of awarding an order or contract and receiving delivery from the vendor. The cost factor for purchasing an item is its unit price. Thus, the total cost of purchasing *m* units of an item is *m* times its unit price. The cost factor for administering a procurement is given in terms of cost per order. The cost of maintenance for *m* units is simply the cost factor, assuming one procurement per item per year.

Purchase prices were known because the data for our test items included their unit prices. However, information on the cost of an ammunition procurement was not available and not included in the Navy analysis. We initially assumed a zero value for this cost. However, a 1989 study of DLA costs to order generated a range of costs from slightly less than $100 to slightly less than $1,500. When inflated to 1998 dollars, these costs range between $135 and $2,015. Our sensitivity analysis tested the latter two values.

## Inflation and Discount Factors

The Navy analysis used a factor of 2.21 percent per year for the inflation of costs. We examined DoD Comptroller inflation factors for FY99 through FY03 and arrived at an average of 2.20 percent. Again, to be on the conservative side of costs, we adopted 2.21 percent as our inflation index for testing.

OMB Circular No. A-94 states that for cost-effectiveness analyses, Treasury borrowing rates should be used to develop discount rates. Appendix C of the circular lists the nominal and real discount rates for notes and bonds for specified maturities (specifically, 3 years, 5 years, 7 years, 10 years, and 30 years). Because we had a specific inflation index to use, we did not select a real rate with a general-use inflation index. Rather we selected a nominal rate and subtracted our inflation index from it to arrive at a real rate. The rate we selected is for a 30-year maturity (the longest period given) and is 6.3 percent. When combined with our inflation index, it yields a real discount rate of 4.09 percent.

# TESTING THE MODEL

## Data Sample

We started testing the model with the two items in the Navy analysis. To provide a more complete range of items, members of the AMICC added 2 Army items, 9 more Navy items, and 5 Air Force items. Table 4-1 lists all 18 items with associated data in order of the dollar value of their annual training requirement. The last item has an annual training requirement of zero and, therefore, does not qualify for economic retention and was omitted from testing. (Items 13 and 17 were the two items used in the Navy analysis.)

*Table 4-1. Data Sample*

| No. | Description | Unit price | Annual training require-ment | Square feet per unit | Pounds per unit |
|---|---|---|---|---|---|
| 1 | Navy MK48 exercise torpedo | $977,500.00 | 464 | 20.42281 | 4,657.000 |
| 2 | Navy MK50 REXTORP torpedo | $1,100,000.00 | 65 | 4.77709 | 1,127.000 |
| 3 | Army M107 HE projectile | $189.00 | 218,000 | 0.11637 | 99.625 |
| 4 | Air Force BDU-50 practice bomb | $735.45 | 37,000 | 0.86612 | 506.667 |
| 5 | Air Force rocket motor | $373.33 | 50,000 | 0.08337 | 24.456 |
| 6 | Navy AMRAAM AIM-120A | $600,000.00 | 11 | 2.26349 | 529.500 |
| 7 | Air Force MJU-10 IR flare | $53.13 | 100,000 | 0.01399 | 0.597 |
| 8 | Navy MK47 GMRT RAM | $33,598.00 | 14 | 2.80122 | 392.300 |
| 9 | Army M557 point detonating fuze | $17.00 | 174,400 | 0.00666 | 2.480 |
| 10 | Navy–Marine location marker | $121.00 | 18,000 | 0.11255 | 16.700 |
| 11 | Navy air-launched harpoon | $495,000.00 | 4 | 8.37310 | 1,694.500 |
| 12 | Air Force target practice 20MM | $5.08 | 300,000 | 0.00097 | 0.664 |
| 13 | Navy 40MM | $19.85 | 29823 | 0.00502 | 0.736 |
| 14 | Navy MK40 laying destructor | $2,908.00 | 134 | 4.58534 | 1,400.000 |
| 15 | Air Force bomb fin | $7,473.86 | 50 | 4.72429 | 340.000 |
| 16 | Navy MK6 dummy UW mine | $582.00 | 221 | 12.28314 | 1,550.000 |
| 17 | Navy 7.62 blank | $0.41 | 190,146 | 0.00034 | 0.077 |
| 18 | Navy standard MS1 RIM-66M-2 | $430,000.00 | 0 | 31.78194 | 4,307.000 |

# Testing with an Infinite Horizon

We first ran the model with the assumption that demand (i.e., the annual training requirement) continues indefinitely in the future. Under this assumption, the economic retention limit is the last year that disposal savings are less than storage savings. For each of our 17 items, we ran the model four times with the parameter settings in Table 4-2.

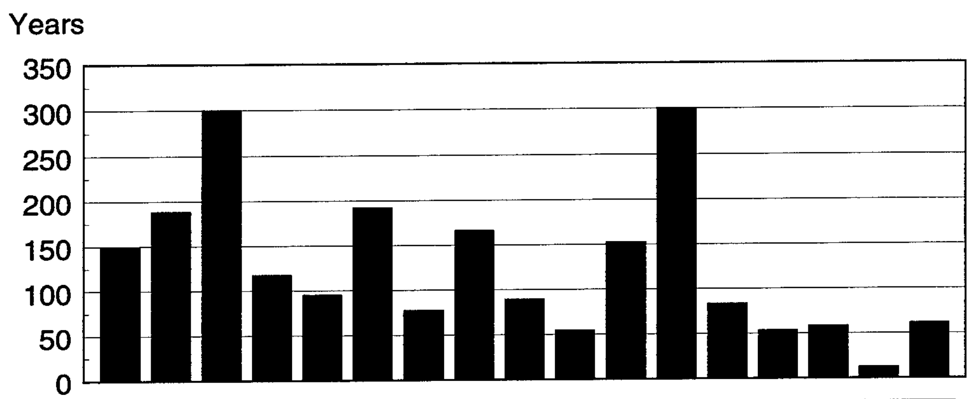
*Table 4-2. Parameter Settings*

| Setting | Storage cost factor | Disposal cost factor | Procurement cost |
|---|---|---|---|
| 1 | SMCA-based estimate | SMCA-based estimate | Repurchase only |
| 2 | DLA-based estimate | SMCA-based estimate | Repurchase only |
| 3 | SMCA-based estimate | MIDAS-based estimates | Repurchase only |
| 4 | DLA-based estimate | MIDAS-based estimates | Repurchase only |

RESULTS

Under setting 1, that is, using the SMCA cost of 4.685 cents per pound of storage, all items had infinite retention limits. Under setting 2, that is, using the DLA cost of $7.89 per square foot of storage, only three items (items 3, 12, and 14) had infinite limits. Figure 4-1 shows the limits by item with infinite limits shown as 300 years.

*Figure 4-1. Retention Limits with DLA Storage Cost (and SMCA-Based Disposal Cost Factor)*



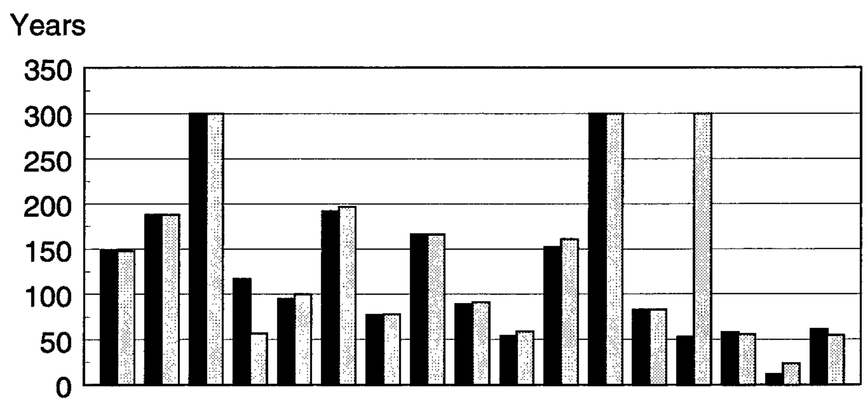

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | 149 | 188 | 300 | 117 | 95 | 192 | 77 | 166 | 89 | 54 | 152 | 300 | 83 | 53 | 58 | 12 | 61 |

With the exception of item 16, all items had limits more than 50 years, and half had limits more than 100 years. These limits are well past the expected 20-to-30-year service lives of the items.

Item 16 has an unusual combination of a large square foot storage per unit and a relatively low repurchase price so that the cost of storage exceeds the cost of repurchasing the item in only 7 years. Its ratio of square footage and unit price was the highest of all the items. It was 0.0211 square feet per dollar while the other items had ratios less than 0.0016 square feet per dollar.

Under setting 3, we obtained the same results as setting 1; that is, all items had infinite levels with the SMCA-based storage cost factor and the MIDAS-based disposal cost factors. Under setting 4, we again had finite levels as we did for setting 2. For purposes of comparison, Figure 4-2 shows the levels for both settings 2 and 4 (as in Figure 4-1, infinite levels are shown as 300 years).

*Figure 4-2. Retention Limits with SMCA- and MIDAS-Based Disposal Cost Factors (and DLA-Based Storage Cost Factor)*




| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SMCA disposal ■ | 149 | 188 | 300 | 117 | 95 | 192 | 77 | 166 | 89 | 54 | 152 | 300 | 83 | 53 | 58 | 12 | 61 |
| MIDAS disposal □ | 148 | 188 | 300 | 57 | 100 | 197 | 78 | 166 | 91 | 59 | 161 | 300 | 83 | 300 | 56 | 24 | 55 |

Figure 4-2 shows that, in most instances, the limits for the SMCA and MIDAS disposal values are close. To test if the difference between the two sets of limits were statistically significant, we applied the *t* test for paired observations. The *t* test examines the differences between the two sets and, with the assumption that the population of differences is distributed normally, computes a critical *t* value to test the hypothesis that they are equivalent. In this case the observed *t* value was –0.42 that is less than–1.771, the critical *t* value for rejecting the hypothesis. Thus, the two sets of limits are not statistically different.

## Sensitivity Testing

In general, sensitivity analysis involves investigating the effect on the optimal solution of making changes in the values of model parameters. In this instance, the values are the estimates for the cost of storage, the cost of disposal, and the cost of procurement. The optimal solution is the economic retention limit generated by our model.

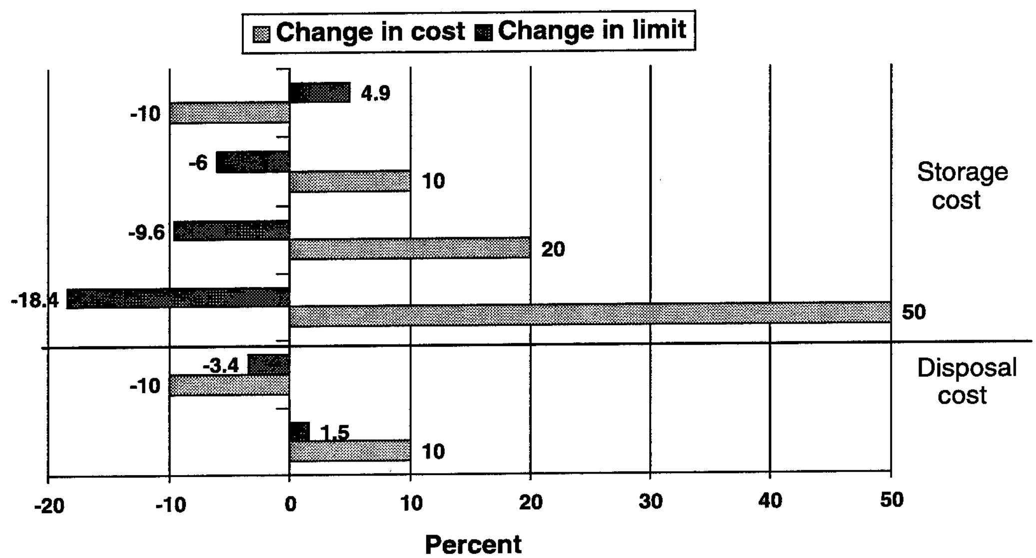
To conduct our sensitivity testing, we started with baseline values of the DLA-based storage cost, the single SMCA-based disposal cost, and a procurement cost equal to the cost of repurchase.[2] We then tested with the sets of changes to parameter values (a total of eight runs for each item) in Table 4-3.

*Table 4-3. Changes to Parameter Values*

| Parameter | Number of runs | Changes |
|---|---|---|
| Cost of storage | 4 | –10, +10, +20, and +50 percent |
| Cost of disposal | 2 | –10 and +10 percent |
| Cost of procurement | 2 | +$135 and +$2,015 |

For each change in a parameter, we computed the change in the retention limit as a percentage and averaged the percentages for all items to determine an overall effect. The results show that retention limits are only affected by changes in the storage and disposal cost factors. The limits derived with either procurement cost change were the same as the baseline limits. The overall results generated by changes in storage and disposal cost factors are shown in Figure 4-3.

*Figure 4-3. Sensitivity of Limits to Changes in Storage and Disposal Costs*




As shown in Figure 4-3, economic retention limits are inversely proportional to the cost of storage. However, the change in the limits is only a fraction of the change in the cost. When the cost change is positive, that fraction decreases as the

[2] We also tested with the SMCA-based storage cost factor, but the limits remained infinite for all items. From these results, we could make no observations or conclusions on the sensitivity of cost factors.

change becomes greater. Although we only tested with one negative cost change, we know from our runs with the SMCA-based value that decreasing the cost will drive all items to infinite limits. These results support the mathematical formulation of the problem as well as our own intuitive logic that as the cost to store goes up, the amount of stock that can be stored economically goes down.

Figure 4-3 also shows that the economic retention limit is directly proportional to the cost of disposal. Again, the change in the limits is only a fraction of the change in the cost. Moreover, Figure 4-3 shows that economic retention limits are less sensitive to the cost of disposal than the cost of storage. These results also support the mathematical formulation of the model and our intuitive logic that as it costs more to dispose of stock, the amount of stock that can be stored economically goes up.

To further investigate the effect of a procurement cost, we investigated values greater than $2,015 and found that the value required to add 1 year to an item's retention limit varies from $2,400 to $15,500,000. The median value is $50,000. These values, particularly those above $50,000, are unlikely as the administrative cost of a procurement. Unless an item has a low dollar value for its annual demand, the inclusion of procurement cost in the retention model does not affect the results.

### CONCLUSION

Our testing of the model with an infinite horizon demonstrated that although the model behaves as expected, it generates limits that are in most cases more than twice the service lives of ammunition items. This conclusion to our decision to test the model with a fixed horizon.

## Running with a Fixed Horizon

We use the terms *fixed horizon* to mean that the demand in the model is limited to a fixed number of years in the future. That is, we experience demand over the fixed horizon and then have zero demand thereafter. By limiting demand in this manner, we are simulating situations where an ammunition item is no longer needed because the weapon system that uses it is taken out of service or because the item itself is replaced with another item. We arbitrarily selected 10 years as our fixed horizon and tested with the demand patterns in Table 4-4.

*Table 4-4. Demand Patterns*

| Pattern | Number of runs | Change in demand each year |
|---|---|---|
| Flat | 1 | None |
| Decreasing | 6 | –1,–2,–3,–4,–5, and–10 percent |
| Increasing (see note) | 6 | +1, +2, +3, +4, +5, and +10 percent |

Note: Although the demand for an item is unlikely to increase as it is being phased out, a military service can increase the usage of an older item to exhaust its stocks before a new item is scheduled to arrive.

Using the model with these demand patterns, we compiled the cost of keeping 8, 9, 10, 11, and 12 years of stock and selected the low cost alternative as the limit for the item.

## RESULTS

With the SMCA cost of 4.685 cents per pound of storage, the low cost limit for all items is 12 years, the maximum limit. Table 4-5 shows the distribution of limits with the DLA cost of $7.89 per square foot of storage and the single SMCA-based cost of disposal and with the finite horizon of 10 years.[3]

*Table 4-5. Distribution of Retention Limits with a Finite Horizon*

| Pattern | Items with 8 years as low cost | Items with 9 years as low cost | Items with 10 years as low cost | Items with 11 years as low cost | Items with 12 years as low cost |
|---|---|---|---|---|---|
| Flat | 0 | 0 | 16 | 0 | 1 |
| Decreasing | 1 | 0 | 14 | 1 | 1 |
| Increasing | 0 | 0 | 0 | 1 | 16 |
| Both increasing and decreasing | 0 | 0 | 1 | 0 | 16 |

In Table 4-5, the item distribution shown for the decreasing pattern represents the low-cost solution for all decreases in demand. The pattern was derived by totaling an item's 8, 9, 10, 11, and 12 year costs for all percent decreases and finding the minimum. However, the results are the same for each percentage decrease as they are for the total. Similarly, the distribution for the increasing pattern represents the optimal solutions for the total and individual percentage runs. Finally, the distribution listed for both decreasing and increasing patterns is the result of

[3] Runs with MIDAS-based disposal cost factors produced results that were identical to those for the single SMCA-based factor except for items 14 and 16. Item 14 moved from 10 to 12 years for flat and decreasing demand. Item 16 moved from 8 to 10 years for decreasing demand.

totaling the 8, 9, 10, 11, and 12 year costs for all decreases and increases and determining the low-cost solution.

As was the case with the infinite horizon, item 16 is the item with lowest number of years of retention.

## Sensitivity Analysis

Runs with the same changes that were used in sensitivity testing with an infinite horizon produced only two minor differences from the baseline results. The other results are identical. The first difference is that item 12 moved from 11 to 10 years for decreasing demand with the 20 percent and 50 percent changes in storage costs. The second was that item 16 moved from 8 to 10 years for decreasing demand with a negative 10 percent change in storage costs.

## Conclusion

Our testing of the model with a fixed horizon demonstrates that the minimum limit should be the period of time that the item is expected to be in service even if demand is expected to decline.

# Chapter 5
# Developing a Practical Model

The results of our testing in chapter 4 argue strongly for retaining as much stock as possessed. Disposing of stock costs money, and disposing of stock that might be used in the future risks the cost of reprocurement. However, unlimited retention is not practical because the demand for every item will eventually end and the accumulated storage costs for any stock remaining would have been an unnecessary expense.

Stock retention is only an issue when stock that is already bought becomes greater than that required for normal operations. Although we have demonstrated that the cost of storage is less than the cost of disposal and potential reprocurement, the cost of storage does exist, and ammunition managers need to be cost-conscious when making stock retention decisions.

In this case, although a strict cost analysis does not produce practical results, it does provide insights on how limits should be set. We want to set limits that avoid the risk of reprocurement and do not dispose of stock that may be needed later. In other words, we want to set limits that provide us with a high degree of confidence that demand for a given known period of time will be covered and any stock above those limits will not be needed.[1]

## Limits Based on Statistical Confidence

We can use statistical estimation theory to set limits that provide the desired confidence level. If we want to meet $x$ years of demand for an item, where $x$ is the remaining life of the weapon system using the item or a number of years selected by management as the planning horizon for ammunition. If $d$ is the annual demand forecast for the item and $e$ is the possible error in that forecast (e.g., we expect to use 10,000 units [plus or minus 10 percent] in the next 10 years), then the confidence intervals for our $x$ years of demand is from the value of $(x)(d)–(z)(e)(x)(d)$ to the value of $(x)(d) + (z)(e)(x)(d)$, where $z$ corresponds to a given level of confidence.[2] To ensure that we cover demand over the $x$ years with some level of confidence, we need to retain only the latter level of stock for the appro-

[1] The period of time is normally equal to the remaining service life of the item. That life can be determined from the remaining life of the weapon system using the item or the scheduled completion of fielding for a replacement item. If neither time is known, management should select a number of years it believes represents the maximum period of usage.

[2] The confidence interval is based on the mean of $(x)(d)$, a standard deviation equal to $(e)(x)(d)$, and a normal distribution for forecast error.

priate $z$. Table 5-1 lists various values for $z$ depending on the desired level of confidence.

*Table 5-1. Values for Levels of Confidence*

| Confidence level | 80% | 85% | 90% | 95% | 99% |
|---|---|---|---|---|---|
| $z$ | 1.28 | 1.44 | 1.645 | 1.96 | 2.58 |

To set our retention limit, we would use $(x)(d)[1 + (z)(e)]$ units of stock, or more simply, $(x)[1 + (z)(e)]$ years of stock. Table 5-2 illustrates the limits for three different levels of confidence and increasing levels of errors when $x$ is equal to 10 years.

*Table 5-2. Example of Limits Based on Statistical Theory of Confidence*

| Expected error | 85% confidence | 90% confidence | 95% confidence |
|---|---|---|---|
| 5 percent | 11 years | 11 years | 11 years |
| 10 percent | 11 years | 12 years | 12 years |
| 15 percent | 12 years | 12 years | 13 years |
| 20 percent | 13 years | 13 years | 14 years |
| 25 percent | 14 years | 14 years | 15 years |
| 50 percent | 17 years | 18 years | 20 years |
| 100 percent | 24 years | 26 years | 30 years |

Our fixed horizon testing shows that if we expect to have demand for a given number of years, the low-cost solution for economic retention is at least that demand. Therefore, if we want to be confident that we can fill demand for a given number of years in spite of our inability to predict that demand exactly, then our low-cost solution is at least those levels shown in Table 5-2.

# RECOMMENDATION

Our analysis of both infinite and fixed horizons demonstrates the validity of setting economic retention limits equal to the number of years of the expected future demand. Therefore, we recommend that the economic retention limit for an ammunition item be based on its remaining service life. That service life should not be greater than the service life of the weapon system that uses the ammunition. The limit may be less if the ammunition has a shelf life (i.e., a maximum time it can be stored before it is unusable). If a service life is unknown because the length of the weapon system's life is uncertain, management can use its planned maximum period of usage.

Some probability exists that demand will vary during that period of time regardless of the horizon selected. Therefore, we also recommend that the computation of the limit consider the normal level of error in predicting future demand and provide a high level of confidence that customer demand will be satisfied throughout the target horizon.

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When stock levels exceed those needed to sustain operations, materiel managers need to decide if they should retain that stock or dispose of it. Economic retention models support that decision-making by trading off the savings from disposal against the savings from retention to arrive at a breakeven point called an economic retention limit.

The Logistics Management Institute analyzed how economic retention limits should be set for ammunition items. Our analysis concluded that (1) the factors involved in the economic retention of ammunition items are the same as those involved in the economic retention of nonammunition items, although the factors have different values; (2) the standard net present value model used to set limits for nonammunition items can be used for ammunition items by modifying the expression for revenues from disposal; and (3) the most economic retention limit for an ammunition item is the level of stock that will cover all known future demand.

The study recommends that the economic retention limit for an ammunition item should simply be based on its remaining service life, but the actual computation should consider the error in forecasting demand to ensure a high level of confidence that future customer demand will be satisfied.

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