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Revised Inventory Management Desk Guide

This TCRP digest provides the results of TCRP Project E-3A, "Inventory Management in a Maintenance Environment," conducted by Susan Thomas and Michael Kilpatrick. This digest is a follow-up to TCRP Research Results Digest 28, "A Desk Guide for Inventory Managers in the Transit Industry," which resulted from the initial study, TCRP Project E-3. This digest summarizes the results from five case studies conducted and analyzed to determine the relationship between inventory control and management, the conditions under which inventory management techniques are best applied, and the solutions to potential problems when applying the inventory control techniques. This digest also identifies how the characteristics of public transit agencies affect the application of inventory control techniques. TCRP Project E-3A's final report, which describes the research approach and the analyses performed during the course of the project, is available as TCRP Web Document 17, at http://www4.nationalacademies.org/trb/crp.nsf.

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INTRODUCTION

The original version of this inventory management desk guide, *It's Okay to Ask,* was developed to assist transit managers and staff with better understanding, evaluating, and managing inventory in a maintenance environment. It summarized inventory control techniques appropriate to the transit industry, along with various decision-making techniques and benchmark references. This revised version of the desk guide expands on the previous edition. Inventory control techniques are explored more fully, using information from a series of case studies. This edition of the desk guide also includes information on the effect of purchasing on the following: material replenishment, storehouse operations, the day-to-day management of parts, and methods for valuing and accounting for inventory. It also presents methods for evaluating inventory performance. The appendixes of the TCRP Project E-3A final report include position descriptions for typical inventory functions, as well as sample forms that can be used for such activities as cycle counting and ABC analysis. The purpose of this desk guide is to

- Provide inventory professionals with helpful information on inventory management techniques;
- Illustrate the practical application of inventory management techniques;
- Assist inventory professionals with improving customer service;
- More fully explore the interrelationships between inventory and other departments, such as purchasing and maintenance; and
- Promote more effective communication.

CHAPTER 1
OVERVIEW TO MANAGING INVENTORY

Just as private-sector organizations have responded to competitive pressures and financial constraints by viewing inventory as a potential source of cost reduction and as a measure of efficiency, public-sector organizations, including public transit agencies, are also focusing on improving the management of their inventories.

The need for inventory is driven by customer demand (that is, the parts, materials, and supplies required by maintenance departments and other customers to perform the day-to-day business activities required by the transit agency). Material requirements can include such diverse items as vehicle parts (for example, parts for bus, rail, inclined plane, and trolley), infrastructure materials (for example, materials for guideway systems, tracks, and bridges), office supplies, and janitorial maintenance supplies.

In this context, the primary goal of inventory is to provide the right item, at the right location and time, at the lowest cost. To meet this goal, inventory professionals work with two major (and sometimes conflicting) objectives in mind: (1) maximize customer service (that is, provide material when the customer needs it) and (2) minimize inventory dollars (that is, control the number of dollars invested in parts and material). Transit agency executives are interested in meeting both of these objectives. Inventory management departments must work with

purchasing departments and customers to reconcile the two conflicting objectives. Ways to accomplish this reconciliation include the following:

- Clear and frequent communication among maintenance, inventory management, and purchasing departments;
- A customer service orientation by inventory management and purchasing departments;
- Active material planning by maintenance, inventory management, and purchasing departments;
- Efficient material flow from the storehouse to the customer site;
- Effective physical control of parts; and
- Enhanced item accuracy.

In addition to providing material to customers, another goal of inventory management is to establish, by centralizing decision making and issue resolution, a full-time authority responsible for materials. The inventory management group also works with the maintenance and procurement departments to forecast and plan the transit agency's material requirements and to monitor the effectiveness and cost efficiency of the agency's material-related activities.

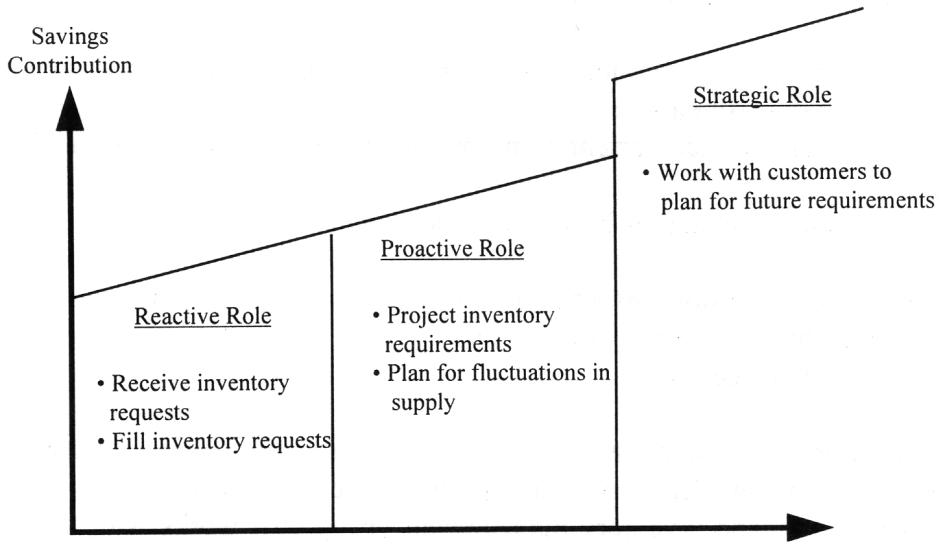
CHAPTER 2
INVENTORY MANAGEMENT ORGANIZATION

Depending on the size of the transit agency, the inventory management function may be at almost any level. It may be at the department level, where the heads of departments report to the senior executive of the company, or it may be at a lower unit level, where inventory personnel report several levels down in the organization. Inventory management may be a stand-alone function or a part of another, area such as maintenance, purchasing, or accounting. This chapter discusses the general duties and responsibilities of the inventory management function, regardless of its location within the transit organization.

2.1 INVENTORY FUNCTIONS

At the most basic level, inventory is responsible for receiving and filling inventory requests from any customer, including other storehouses. As the inventory function grows, the department begins projecting inventory requirements, on the basis of information from past usage and from user input, and then anticipating and planning for future requirements. Figure 1 shows the progression of inventory functions.

Figure 1 Inventory Functions



Inventory Management's Role Broadens

As inventory management organizations mature, from only responding to customer requests to also anticipating customer requirements and actively planning for them, parts availability increases and the number of dollars tied up in inventory begins to decrease. These changes result because organizations that do not plan for customers' material requirements often either overstock material or waste time and money with "emergency" purchases or shipments. Inventory management organizations that operate proactively can project inventory requirements both for the near term and over several years and plan for the increase or decrease in inventory stock accordingly.

2.2 ORGANIZATIONAL RESPONSIBILITIES

Inventory is often divided into three groups: management, material distribution and warehousing (including stores), and material planning. Along with purchasing departments, these groups are responsible for providing customers with the materials needed to perform jobs. The following sections discuss how the three inventory groups, as well as customers, work to ensure effective inventory management.

2.2.1 Management

People in this area have overall responsibility for inventory planning and control, storekeeping, storeroom security, material handling and distribution, shipping, and receiving. In other words, they are responsible for ensuring the availability of material to meet customer needs. Management is also responsible for setting inventory goals and objectives, in accordance with the agency's overall goals and objectives, and ensuring constant adherence to inventory management policies and procedures. In addition to overseeing and supporting staff, responsibilities include

- Controlling inventory investment dollars;
- Establishing performance measures;
- Monitoring inventory performance;

- Centralizing or decentralizing decision making and issues resolution;
- Monitoring the effectiveness and cost efficiency of inventory activities;
- Developing long-range plans for new and existing parts acquisition, inventory levels, warehousing, and distribution;
- Overseeing the addition of new items to and the removal of obsolete items from inventory;
- Analyzing processes;
- Determining requirements; and
- Assessing new information systems and technologies.

2.2.2 Material Distribution and Warehousing (or Stores)

People in distribution and warehousing (that is, stores) are responsible for the distribution of inventory materials to all storage or using locations. They are also responsible for the physical security and safekeeping of material at all stores locations and for all storekeeping activities, including material receiving, put-away, and material picking and shipping. Other responsibilities include

- Maintaining accurate inventory records;
- Managing the physical layout of storehouses, including bin location assignments;
- Determining the physical movement and distribution of material throughout the organization;
- Receiving and storing material;
- Issuing stock material in response to a material request from customers;
- Conducting cycle counts, annual physicals, or both;
- Reconciling discrepancies between cycle count and annual physical inventory;
- Developing and operating truck and route schedules for distribution of material; and
- Working with purchasing departments to resolve vendor-related problems with timing, quality, quantity, and delivery.

2.2.3 Material Planning

People in material planning are responsible for inventory planning and control, including planning materials requirements on the basis of customer forecasts and then monitoring usage against the plan. They are also responsible for developing replenishment strategies and determining the required quantity and availability of material to meet customer needs. Additional responsibilities include

- Classifying, or stratifying, stock material into commodity classes;
- Using such methods as the ABC system of inventory control;
- Making sure material is on hand when needed;
- Determining where and how much material is stocked (including storehouse locations and remote sites);
- Projecting material demand;
- Deciding whether to use stock or nonstock items;
- Maintaining the catalog of inventory items; and
- Assisting purchasing departments with determining the best supply method.

2.2.4 Customers

Customers also are responsible for working with inventory to ensure that material is on hand and available when needed. Their responsibilities include

- Ensuring that material requests are authorized and complete,
- Writing all material specifications,
- Completing purchase requisitions for nonstock material,
- Determining material needs and schedules,
- Identifying "must-have" material at remote sites,
- Controlling expensed items,
- Providing quality feedback to inventory management about its level of service, and
- Adhering to inventory security and record-keeping policies and procedures.

CHAPTER 3
INVENTORY DECISIONS

Inventory decisions usually occur at three levels: the management, or policy, level; the material group level; and the item level. Decision-making responsibilities change from one level to the next, from establishing overall goals, to determining how the goals will be implemented, to working with inventory items.

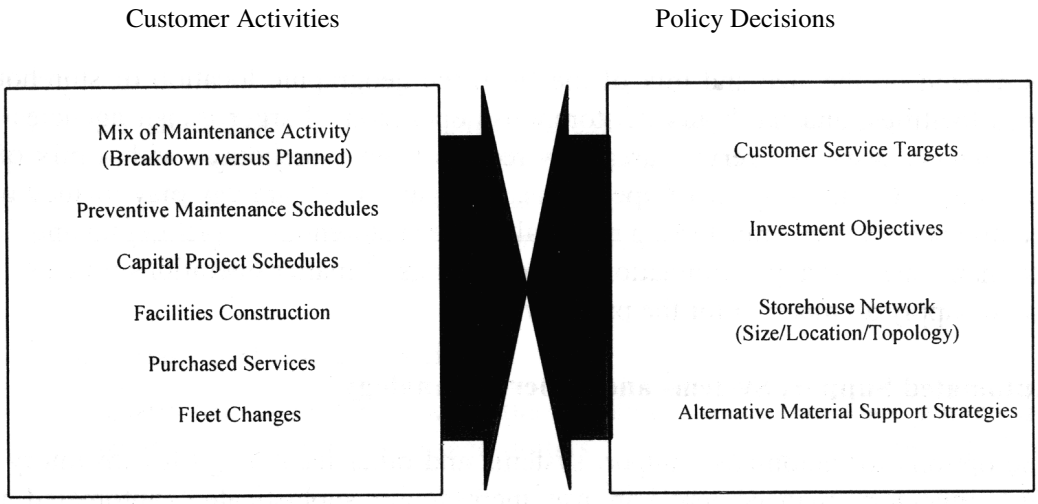
3.1 POLICY-LEVEL DECISIONS

Management- or policy-level decisions affect the entire inventory and are generally made by the individual who has overall responsibility for directing inventory management. The participation of the transit agency's top management is also essential for establishing the importance of inventory performance and for directing the focus of inventory activity through defining and monitoring specific goals and objectives. Decision making at this level focuses on establishing overall goals, strategies, or both for

- Customer service,
- Inventory investment,
- Inventory accuracy,
- Inventory support,
- Distribution/consolidation, and
- Automated support systems and other technology.

Figure 2 illustrates how customer needs affect policy.

Figure 2 Role of Customers in Policy Decisions



3.1.1 Customer Service

Customer service goals are established to provide inventory managers with a means for measuring the level of service provided by inventory management departments to their customers. A target, such as 95 percent, is established for the number of times a material request is filled *at the time of the request* (with a 95-percent target, inventory management should strive to fill material request orders 95 percent of the time). See Chapter 7 for specific measures of customer service available to inventory managers.

3.1.2 Inventory Investment

Inventory investment goals focus on the total value of the inventory and on the average number of months on hand for inventory items. Similar to customer service, these goals are established to provide inventory managers with a means for measuring inventory performance. Chapter 7 discusses specific measures of inventory investments.

3.1.3 Inventory Accuracy

Inventory accuracy defines how well the inventory records, specifically the quantities on hand, match the actual quantities in the storeroom. Accurate records are a prerequisite to effective inventory management. Chapter 7 includes specific inventory accuracy measures.

3.1.4 Inventory Support

Inventory managers are also responsible for developing strategies for the effective and efficient provision of inventory material. Such strategies may involve the type of storehouse network (for example, parent/child or wholesale/retail, hub and spoke, and independent storehouses), the inclusion or exclusion of capital material, the use of consignment and vendor-maintained inventory, procedures for inventorying and tracking repairable components, inventory valuation methods, or any combination of these things.

3.1.5 Distribution/Consolidation

Strategies for determining how material should be physically stored and distributed to customers depend on the size and mix of the fleet, the geographic location of storehouses and maintenance facilities, and the hours of storehouse operation. Larger transit agencies with big fleets and a widely dispersed service area may require many storehouses with a mix of general and special stock. For these types of operations, the distribution strategy may include using one or more central warehouses, transferring material between storehouses, picking up and delivering material to many sites, or any combination of these things. Smaller operations may use only one storehouse to supply all material for the property.

3.1.6 Automated Support Systems and Other Technology

The options for automated support systems and other technology for inventory are ever advancing. Inventory management can use increasingly sophisticated, automated materials management systems, as well as technology like RF bar code and other data-gathering devices, automated storage and retrieval systems (ASRS), electronic parts catalogs and imaging, ecommerce, and electronic data interchange (EDI).

3.2 MATERIAL GROUP-LEVEL DECISIONS

Material group-level decisions focus on executing the strategies developed at the policy level as applied to the different categories of material. These decisions focus on such activities as grouping items by ABC classification and using commodity classes to control inventory decision making.

3.2.1 Grouping Items by ABC Classification

Grouping items into classes (that is, ABC) allows inventory managers to focus first on the items that require the most frequent attention, thus ensuring that there are enough of these items on hand when needed. Items that require less attention are focused on next, and items that require the least amount of attention are focused on last. This approach does not determine which items are more "important" than others (for example, a 50-cent bolt can hold a bus or locomotive out of service), but simply assists with determining how material is ordered and how often. This approach prevents dollars from being tied up in items that are sitting idle, as well as prevents critical parts from running out. Grouping inventory using the ABC approach

- Improves overall material availability while reducing excess and obsolete material,
- Focuses on material with the highest dollar effect,
- Minimizes the probability and severity of stockouts, and
- Effectively uses inventory management staff time.

An ABC analysis of inventory involves the following steps:

(1) Establishing levels for analysis, such as A, B, and C (or as many classes as warranted), on the basis of the items' characteristics;

(2) Assigning a level for each item on the basis of the criteria established in the previous step; and
(3) Applying a degree of control in proportion to the value of the items in the group.

"A" items are defined as those with the greatest annual dollar usage, or the high-value items; "B" items are those with a lesser amount of annual dollar usage, or the medium-value items; and "C" items are those with the lowest annual dollar usage, or the low-value items. Table 1 shows characteristics of the different item levels.

TABLE 1 ABC item-level characteristics

A Items	Highest annual dollar usage items, or items with a high value	Accounts for about 70% of the total annual inventory usage dollars. Approximately 10-20% of all items in the inventory can typically be classified as "A" items.
B Items	Medium annual dollar usage items	Accounts for about 20% of the total annual inventory usage dollars. Approximately 30% of all items in the inventory can typically be classified as "B" items.
C Items	Lowest annual dollar usage items	Accounts for about 10% of the total annual inventory usage dollars. Approximately 50-60% of all items in the inventory can typically be classified as "C" items.

An example of the ABC classification process is presented below. (Dollar figures are for illustrative purposes only. Actual dollar levels should be based on the size of the agency's operation and on the total inventory value.)

1. Calculate the annual dollar usage for each item in the group (multiply total units issued in the year by unit cost);
2. Calculate the total annual dollar usage (add usage for all items);
3. Calculate each item's percentage of the total usage (item usage/total usage);
4. List the items in reverse order on the basis of percentage of total usage;
5. Calculate the cumulative percent of total at each item's position;
6. Examine the annual usage distribution; and
7. Establish the breakpoints for A, B, and C items.

In addition to annual dollar usage, other factors may affect the classification of an item. Items may be reclassified on the basis of the following criteria:

- Unit cost,
- Length and variability of lead time,
- Storage requirements,
- Pilferage risks and shelf life,
- Cost of a stockout, and
- Scarcity.

Table 2 exemplifies how the factors in the previous list can be applied to adjust an item class.

TABLE 2 Adjusting item class on the basis of various factors

Factor	Class Adjustment
Unit cost greater than $2,500	A item
Lead time greater than 12 months Special storage requirements High "street value" Scarce commodity Unusually high cost of stockout	Raise from C to B or from B to A

Each of the ABC classes requires different levels of control. For example, because A items are responsible for the greatest annual dollar usage or meet at least one of the criteria in Table 2, they require the greatest degree of control. B items, because of their lower item cost and lower frequency of replenishment, have a lower degree of control. C items, because of their lowest item cost and lowest frequency of replenishment, require the least amount of control. Because B and C items generally have a lower value and lack the item characteristics that would warrant a higher classification, they can probably be ordered in greater quantities and less frequently. As a result, B and C items generally may not be reviewed again until they are ready for reorder.

Appropriate control of A items may involve monthly evaluation of forecasts and of the forecasting method; frequent (perhaps monthly) cycle counting, with low tolerances for inaccuracy; immediate updating of records; frequent review of demand requirements, order quantities, and safety stock (this review usually results in relatively small order quantities); and close follow-up and expedition to reduce lead time.

Appropriate control of B items may involve measures similar to those for A items, but with control activities usually taking place less frequently.

Appropriate control of C items may involve the basic rule of "have them"; simple or no records, perhaps with a periodic review of physical inventory or a two-bin system; large order quantities and safety stock; storage in areas readily available to customers or storekeepers, such as with floor stock; counting items infrequently (for example, annually or semiannually) with "scale" accuracy (that is, weighing rather than counting) acceptable.

Table 3 shows examples of control by ABC class.

TABLE 3 Examples of control by ABC class

Inventory Control Factors	A Items	B Items	C Items
Estimating demand	Each item	% change by commodity	By exception
Cycle counting	Once per month or quarterly	Once per quarter or every 6 months	Once or twice per year
Cycle count exceptions tolerance	Exact match	Within 2%	Within 5%
Replenishment frequency	6-12 times per year	2-4 times per year	1-2 times per year
Stocking levels	1-2 months on hand	3-6 months on hand	6-12 months on hand
Service level targets	95+%	95+%	99.999%
Reorder monitoring	Day-to-day	Once per week	Once per month

Table 4 lists examples of item rankings, in descending order, by percentage of annual dollar usage. Classes are assigned according to each item's annual dollar usage. Although the cutoffs between the different classes are somewhat arbitrary (but based on the 10-20-70 rule), these items show a distinct value differential between Items 4 and 5 and between Items 9 and 10.

TABLE 4 Examples of item rankings

Item #	Annual Usage ($$$)	Percentage of Total Inventory	Cumulative Percentage	Class
7	$181,500	41.4	41.4	A
4	116,000	26.4	67.8	A
5	37,500	8.6	76.4	B
8	37,500	8.6	85.0	B
9	30,000	6.8	91.8	B
10	18,000	4.1	95.9	C
3	8,000	1.8	97.7	C
1	5,000	1.1	98.8	C
2	3,750	.9	99.7	C
6	1,360	.3	100.0	C

After ranking items, in descending order, by percentage of annual dollar usage, reorder the items, grouping them by ABC class (see Table 5). The general rules for applying ABC classification apply in this case. Once classes are assigned, controls can be established to monitor performance.

TABLE 5 Reordering items by ABC class

Class	Items	Percent of Items	Percent of Dollar Volume
A	7,4	20	67.8
B	5,8,9	30	24.0
C	3,1,2,6,10	50	8.2

The customer also has a role in ABC analysis. This role includes providing input on projected usage; communicating expected changes in usage amount, pattern, or both; communicating the cost of a stockout (that is, item criticality); and providing other relevant information.

3.2.2 Using Commodity Classes to Control Inventory Decision Making

Another method of categorizing inventory is to group "like" commodities into classes and subclasses. Using commodity classes will assist in improving item control. Other benefits of using commodity classes include

- Easier identification of items,
- Grouped analysis of item information (for example, lead times and usage),
- Combined replenishment methods, and
- Combined bids and purchases.

Commodity classes are often organized by major and minor components for rolling stock and by types of services or products for nonrolling stock inventory. Examples of the numbering scheme and the inventory classes and subclasses for rolling stock and other inventory items include the following:

01 Buses
011 Brake, steering, axle and wheel components
012 Cab, body and frame structural components
013 Seats
014 Heaters
015 etc.

02 Rail equipment
021 Braking systems
022 Controls
023 Power systems
024 Right-of-way
025 etc.

33 Chemicals
331 Absorbents
332 Bus wash chemicals
333 Degreasers
334 etc.

3.3 ITEM-LEVEL DECISIONS

Decision making at the inventory item level focuses on forecasting demand, determining replenishment levels, and determining inventory volumes and stocking points. Decisions about item inventory forecasting and about replenishment determine how much to order and when to order. These decisions are driven by demand patterns, the variability of supply and demand,

capital project schedules, lead times, and item class. Other factors to be considered in forecasting volumes and timing include the vendor pool, industry practices (for example, lot sizes and price breaks), shipping schedules, market conditions, and funding or budget-level constraints.

3.3.1 General Item Description Guidelines

All items should follow an established numbering and naming convention. All descriptions must be unique and should consist of

- A standardized key word (for example, gasket, bolt, or filter),
- Adjectives according to standard industry practice (for example, hexagonal or twoply),
- Size or capacity (for example, 16 oz, 50 ohm, or 32 ft), and
- Other identifiers as necessary (for example, material type, finish, or color).

Manufacturers' or vendors' part numbers or names should not be included in the description unless the number or name is the description, such as proprietary electronic circuit boards. Units of measure should be excluded from the item description, except for small items normally stocked in large quantities (for example, a box of nails or adhesive bandages). The item description should generally exclude information stored in other fields (for example, vehicle series and hazardous material designation).

3.3.2 Forecasting Material Demand

Forecasting techniques for maintenance requirements differ from forecasting techniques for project materials. Consideration should be given to such factors as variation in lead times, schedules, historical and projected usage, safety stock, unit cost, seasonality, service-level objective, and market conditions.

Demand for inventory items is forecasted to cover fluctuations in demand and to accumulate stock in advance of demand. Material requirements are accurately forecasted to ensure the availability of material (that is, it is determined what items should be ordered, when and how they should be ordered, and in what quantities they should be ordered).

Good forecasting requires recognizing the two conflicting inventory management objectives discussed earlier: that of maintaining a high level of customer service and that of minimizing inventory investment (that is, minimizing the number of dollars tied up in inventory). Too often, there is a tendency to over-stock in order to satisfy the first goal or under-stock to satisfy the second.

Inventory managers should focus most of their forecasting efforts on meeting inventory objectives. It is inefficient to spend the same amount of time forecasting for such low-cost, highvolume items as nuts and bolts as for such items as traction motors and brake shoes. Do certain items like common nuts and bolts need to be tracked at all, or only at a gross level? Can items like common nuts and bolts be set out in bins, with the bins being refilled as they get low and

inventory workers not worrying about charges on a per-item basis? Decisions like these can be made easier by applying the principles of ABC analysis and commodity classifications.

Different methods should be used to forecast requirements for different types of material. In other words, similar types of items should be classified together. For example, the forecasting techniques applied to items used on a regular basis should not be applied to items used on a seasonal basis. The key to good forecasts is to use the two or three most appropriate methods (not just one) that work best with the different types of materials.

Most inventories in the transit industry are composed of two broad categories of materials. The first category includes materials whose demand is based on regular or scheduled usage patterns. Such materials include

- Project materials whose demand depends on the project schedule,
- Routine maintenance parts for repair work done on a scheduled basis (for example, a 30,000-mi replacement or a 2-year-check item),
- Materials for routine, scheduled-frequency work (for example, materials for overhauls and rehabs), and
- Some supplies whose demand is based on regular or scheduled activities (for example, standard office supplies and janitorial and safety items).

The second broad category of materials consists of items that are used on a random basis as breakdowns occur or as repairs are needed. This category includes

- Repair parts, including many consumable items (that is, those replaced and discarded) or repairable items (that is, those repaired for later use) and including critical items (that is, those that require 100-percent availability);
- Materials for first-time, routine work (for example, parts for new and different buses or locomotives); and
- Materials for facilities maintenance.

There are many forecasting methods available based on type of demand for materials stocked in inventory. Generally, demand is either dependent or independent. *Dependent demand* is when material requirements are determined by customer decisions. Requirements for material with dependent demand are calculated. This type of material includes planned maintenance, capital projects, and component rebuild. *Independent demand* is when material requirements are determined by uncontrolled factors. Requirements for material with independent demand are forecasted. Unscheduled, or breakdown, maintenance is an example of independent demand.

In addition, independent demand can be either *stable* or *intermittent.* Some material may have a *stable* demand pattern, even though the demand is independent. For example, demand for light bulbs in facilities may be fairly constant, even without a plan for scheduled replacement, and demand for ice melt chemicals may show a cyclical pattern, even though weather varies from year to year. Conversely, some material will be *intermittent,* with no distinguishable pattern. Different replenishment methods should be used, depending on the type of demand (see Table 6).

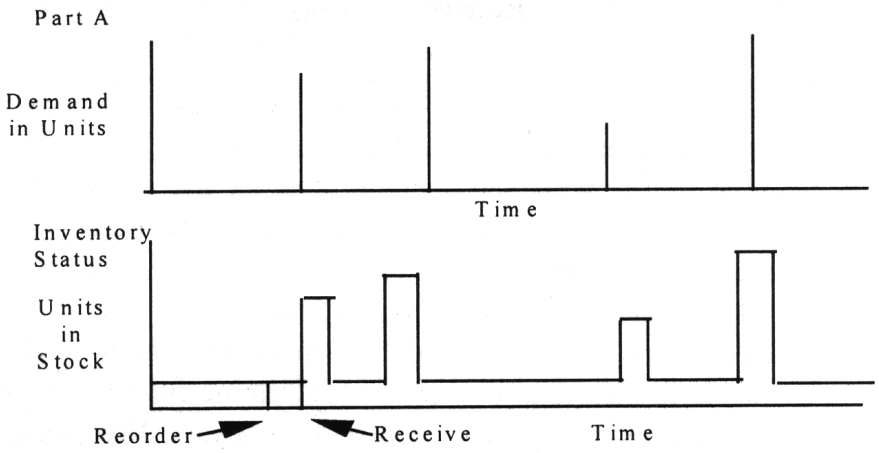
TABLE 6 Replenishment methods according to demand

Demand	Maintenance Requirements	Replenishment Method
Stable Independent Demand	Unscheduled Maintenance (Forecasted Requirements)	Fixed Period
Intermittent Independent Demand	Unscheduled Maintenance (Forecasted Requirements)	Min/Max Reorder Point/EOQ Two Bin System
Dependent Demand	Capital Projects Planned Maintenance (Calculated Requirements)	Fixed Schedule Fixed Order

When customer decisions determine material requirements (that is, when the demand is dependent), the inventory manager can fairly ascertain the demand. Examples of material requirements that fall under this category include capital projects and planned maintenance activities. Because this information should be known and available in advance, most material requirements can be easily calculated. For ordering material that is based on dependent demand with scheduled usage, an appropriate method would be either fixed schedule or fixed order. With both methods, the exact amount and type of material required is known, and delivery can be scheduled for specific dates and locations.

Figure 3 schematically depicts the relationships between demand, inventory stock status, reorders and receipts, and timing.

Figure 3 Dependent Demand

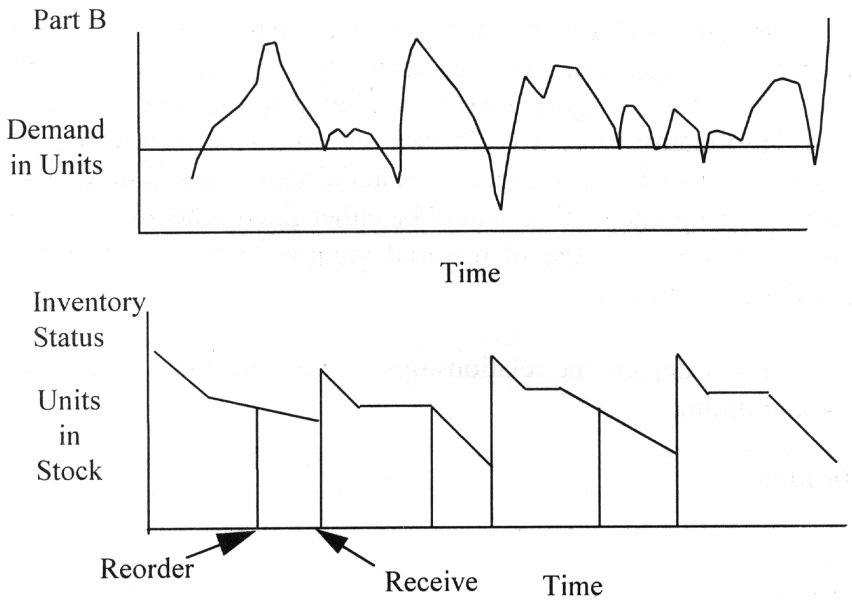


Independent demand is determined by uncontrolled factors. This type of demand includes unscheduled maintenance and other activities whose material requirements cannot easily be calculated in advance. Because the exact frequency and timing of breakdowns or unscheduled repairs cannot be known in advance, forecasting for this type of material must be done in a different manner than for scheduled material requirements. For items whose usage cannot be easily projected because of irregular demand patterns (which is often the case in the transit industry), some other method for determining stocking quantities must be applied, such as

min/max, fixed period, and reorder point/economic order quantity (EOQ). However, as discussed in later sections of this desk guide, using the EOQ method requires careful planning for every item in the inventory.

Figure 4 shows the independent demand pattern. Unlike the dependent demand schematic, the demand (or need) for inventory is not constant; it fluctuates as material is needed. As a result, reordering of material follows the use of the material. Reordering is not constant and does not have a discernible pattern. Section 3.3.3 discusses the types of replenishment methods available that are based on material demand patterns.

Figure 4 Independent Demand



The forecasting methods discussed are the most common methods available. Other computerized forecasting techniques include the weighted-average and exponential smoothing techniques. In an example of the weighted-average method, the computer system tracks the usage rate for a given number of periods, say 12 months. The system then forecasts the material demand for the next month by averaging the prior 12 months. However, in calculating the average, the system applies a heavier weight to specific months identified by the material planner, such as more recent months. In exponential smoothing, the system uses a formula to smooth the peaks and valleys in historical data when forecasting future demand. Other methods for forecasting material requirements include regression analysis, Box Jenkins, Shisken time series, and various other economic models.

Regardless of the method chosen, good forecasts should include the following:

- Historical data (when available) for each part number or unique item (including, if possible, usage on a per-month basis for the past 3-5 years).
- A plan for controlling the inventory material. By using a simple ABC analysis based on annual dollar usage (with A items being those with the highest annual dollar usage), the focus can be on planning for and controlling the approximately 20

percent of inventory items that account for approximately 80 percent of the dollars invested in the inventory.

- A determination of lead times. Lead time has two components: internal, or administrative, lead time; and vendor lead time. Lead time is the total time required to replenish an inventory item, from the time an ordering or reordering need is recognized to the time the item is received in inventory. It includes all steps of the purchasing process, from requisitioning to purchasing, to receiving, to physically adding the item to the inventory. Determining lead times is perhaps the most critical, and often the most difficult, when forecasting material needs. Lead times can be determined for each single item or for similar items, such as common hardware; however, lead times cannot generally be applied to a vendor's entire stock of parts or materials. Lead times are affected by such variables as whether the item is off-the-shelf or made-to-order, the scheduling of production runs, the purchasing method used, and the minimum and maximum quantities ordered.
- Stocking quantities that are most often composed of monthly demand plus safety stock. The safety stock component is derived from the lead time plus the ordering frequency and minimum and maximum quantities ordered. It is the material carried on hand to reduce stockouts when forecasts underestimate supply.
- Input from maintenance departments regarding changes in parts usage because of such factors as changes in fleet configuration and the addition of new models.

Results that can be achieved through good material forecasting include

- **Reduced annual maintenance costs.** Customers no longer "run to the store" to buy parts and materials at premium costs.
- **Reduced equipment downtime.** Materials needed are on hand, and lead times are no longer a problem.
- **Better inventory management.** Dangers of having excess inventory on hand or of running out of needed material are greatly reduced.
- **Improved morale.** Maintenance staff members are satisfied that they will get their materials when they need them, and inventory staff have developed a team relationship with maintenance.

3.3.3 Determining Replenishment Methods

There are many methods available for replenishing inventory material. This section presents six of the most commonly used: For dependent demand, there are the fixed-schedule method and fixed-order method. For independent demand, there are the two-bin system method, min/max method, fixed-period quantity method, and reorder point/EOQ method.

3.3.3.1 Fixed-Schedule Replenishment Method

The fixed-schedule method of inventory replenishment is used when the time and quantity for ordering material are fixed. Types of material that fall into this category include material for projects like fleetwide change-outs and scheduled maintenance activities and frequently used material like filters.

Things that should be established before determining whether the fixed-schedule method of replenishment is appropriate include

- A project or planned maintenance schedule,
- A bill of material (BOM), or
- Inventory record status data (for example, quantity available, quantity on order, and lead time).

Figure 5 shows the sequence of events for ordering material using the fixed-schedule method. The chart shows the date the order is to be initiated based on the lead time for the item. The item is held in inventory for a small amount of time before it is used.

Figure 5 Fixed-Schedule System

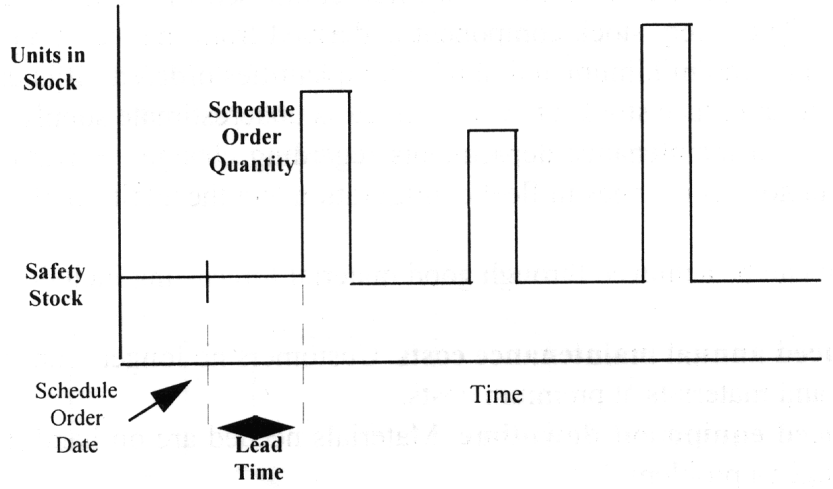


Table 7 is a sample fixed-schedule worksheet, showing actual movement of inventory, assuming that there are 2 months of total lead time, 7 items on hand, and 10 items on order. It shows the demand (that is, gross requirements) for each month and the beginning inventory level (that is, the quantity available).

TABLE 7 Sample fixed-schedule worksheet, assuming that there are 2 months of total lead time, 7 items on hand, and 10 items on order

	Month 1	Month 2	Month 3	Month 4	Month 5
Gross Requirements	0	10	15	5	5
Quantity Available	7				
Schedule Receipts	0	10	0	0	0
Projected Available					
Net Requirements					
Planned Release					

Table 8 shows the completion of the worksheet. Complete the worksheet by (1) calculating the net requirements (that is, gross minus available plus receipts; note that a negative outcome means sufficient quantity is available for the month) and (2) carrying the net to the next month as the quantity available or ordering 2 months before another net requirement is needed.

TABLE 8 Completion of sample fixed-schedule worksheet, assuming that there are 2 months of total lead time, 7 items on hand, and 10 items on order

	Month 1	Month 2	Month 3	Month 4	Month 5
Gross Requirements	0	10	15	5	5
Quantity Available	7	**7**	**7**	**0**	**0**
Schedule Receipts	0	10	0	0	0
Projected Available	**7**	**17**	**7**	**0**	**0**
Net Requirements	**-7**	**-7**	**8**	**5**	**5**
Planned Release	**8**	**5**	**5**	**-**	**-**

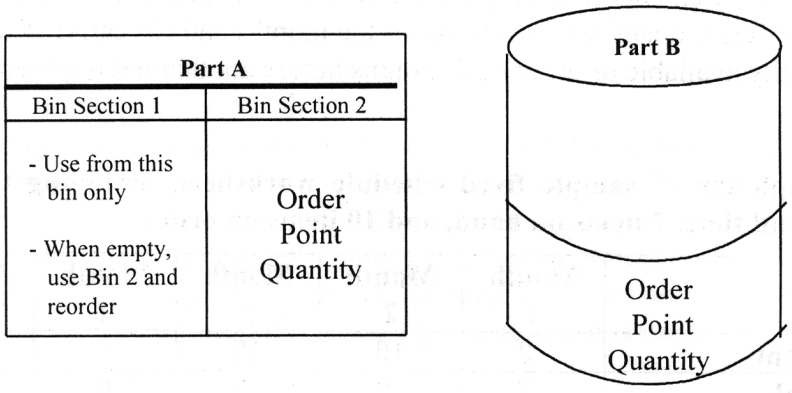
3.3.3.2 Fixed-Order Replenishment Method

The fixed-order method of material replenishment occurs when the size of the order is stable (that is, fixed), but the timing of material delivery is based on actual demand. This method differs from the fixed-schedule method because the timing of the orders and the quantities depend on actual demand. The fixed-order method of material replenishment is commonly used for seasonal items and for items that the transit agency does not want to stock all year around. Types of material that fall into this category include road salt, sand, and materials for air conditioning. Because this material is not stocked all year around, the computer system should be programmed to flag the material on a fixed-order basis. With this method, material will not keep showing up on reorder reports, but appear only at the time the order must be placed.

3.3.3.3 Two-Bin System Replenishment Method

The two-bin method is often used for low-value, frequently used material when exact requirements or usage cannot be planned. Materials frequently used with the two-bin system include common nails, nuts, bolts, and other low-value, high-usage items. As shown in Figure 6, the two-bin method for replenishing material is easy to implement and equally easy to use for tracking usage. In the Part A diagram, items are used from the first section of the bin only. When all the material is used, the second section of the bin is opened for use and an order is placed with the vendor for a refill. In the Part B diagram, the item is placed in a barrel or keg. When the item level falls to the lower section of the keg, the item is reordered.

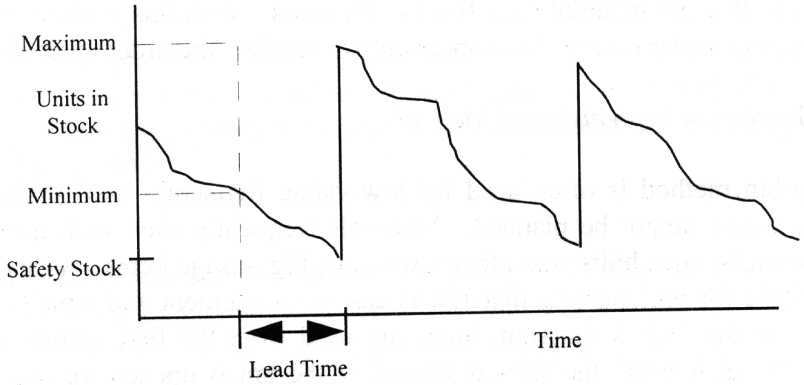
Figure 6 Two-Bin System



3.3.3.4 Min/Max Replenishment Method

The min/max method is used for items whose material demand (that is, usage) constantly changes. The method is based on the maximum and minimum amounts of material required. With this method, maximum and minimum numbers of units to be stocked, as well as the amount of safety stock required until the next order is filled, are determined. Whenever the inventory on hand reaches the minimum stocking level or reorder point, an order is placed for the number of items necessary to reach the maximum stocking level. The advantage of a min/max system is that different minimum and maximum levels can be set for each class of items or for individual items. Replenishment is triggered when stocking levels reach the minimum, regardless of the amount of time elapsed since the last order. Figure 7 displays the min/max system.

Figure 7 Min/Max System

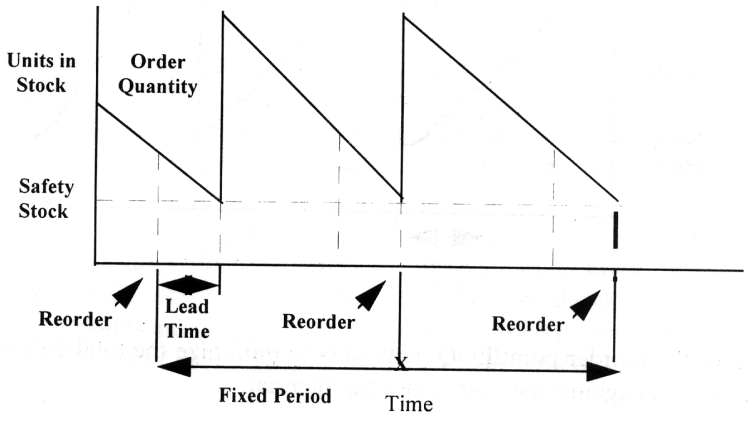


3.3.3.5 Fixed-Period Quantity Replenishment Method

Fixed-period quantity is the fifth method used for computing what to order to meet the independent demand. It is similar to the fixed-schedule method; however, while the fixed-schedule method is used for dependent demand (that is, for when the requirements are known in advance), the fixed-period method is applied when material requirements cannot be planned in advance (that is, when material requirements are determined by uncontrolled factors) but have demand that, once known, is stable. Examples of materials that can be applied to this

replenishment method include normal-wear items that tend to fail in predictable and stable patterns, such as light bulbs and fuses. Figure 8 shows the steady decline associated with a stable-demand pattern that is at a fairly constant level over time.

Figure 8 Fixed-Period Quantity System



3.3.3.6 Reorder Point/EOQ Replenishment Method

A reorder point/EOQ system requires that for every item stocked in inventory, a determination is made of the point at which the item will be ordered and of the most cost-efficient quantity to order. The method also assumes a fairly constant lead time. Figure 9 shows the flow of the inventory process using the reorder point/EOQ method. As is shown, all variables except time are constant. Assumptions for using the reorder point/EOQ method include that

- Item cost does not vary,
- Order size does not vary,
- Lead time is constant and known, and
- Storage costs are linear (that is, they increase steadily as space increases).

The reorder point/EOQ system is most effectively used with a central storehouse that supplies materials to a number of smaller storehouses. The central warehouse must have the capacity to store excess material until needed by the secondary storehouses.

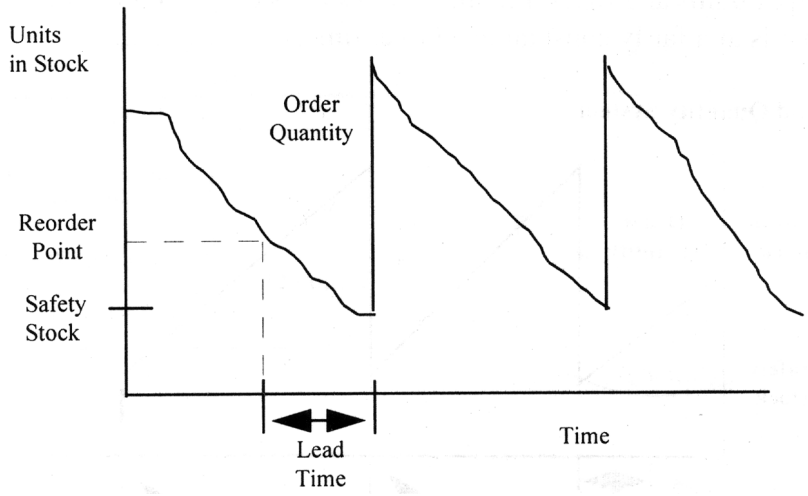
The following represents a typical reorder point calculation:

Reorder Point = Average Demand Rate x Lead Time + Safety Stock

$$\text{Safety Stock} = \text{Demand Rate Standard Deviation} \times \text{Safety Factor} \times \sqrt{\frac{\text{Lead Time}}{\text{Demand Period}}}$$

(For 95-percent assurance, a safety factor of 1.65 is used; for 99-percent assurance, a safety factor of 1.96 is used.)

Figure 9 Reorder Point/EOQ System

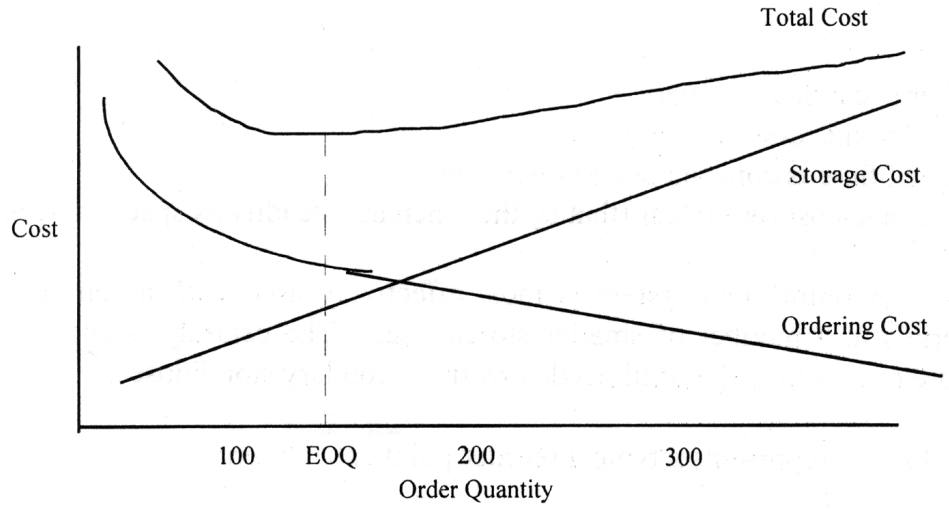


The goal of the reorder point/EOQ method is to minimize the total cost by balancing the cost of ordering material against the cost of storing material:

- Ordering decreases as order quantity increases,
- Storage cost increases as order quantity increases, and
- Total cost = ordering cost + storage cost.

Figure 10 displays the EOQ formula.

Figure 10 EOQ Formula



EOQ is calculated as follows:

$$EOQ = \sqrt{\frac{2 \times \text{Ordering Cost} \times \text{Annual Usage Units}}{\text{Average Price} \times \text{Carrying Cost \%}}}$$

Because it may be difficult to meet the requirements for using a reorder point/EOQ system (for example, constant and known demand and lead time, instantaneous replenishment, and linear storage costs), the min/max method would be more appropriate for determining material requirements for irregular usage patterns.

3.4 DETERMINING INVENTORY VOLUMES AND STOCKING POINTS

Factors in determining inventory volumes include lead times, project schedules, historical and projected usage, safety stock, unit cost, seasonality, service level objectives, and market conditions. Variances between actual and planned dollars may be due to an increase or decrease in volume, in the scrap rate, in the cost of material, in lead time, or any combination of these factors.

Decisions on inventory stocking points are required when more than one storehouse is used to supply material, either directly to customers or through a central warehouse. Determining stocking points and where an item should be stored depend on the characteristics of the item and the availability of space. Table 9 shows guidelines for determining storage locations.

TABLE 9 Guidelines for determining storage locations

Item Characteristic	Central Storehouse	Satellite Site
Urgency of need/Demand pattern	Can receive next day	Critical to be at site
Degree of physical control required	High	Low
Cumbersome to distribute?	No	Yes
Special storage requirements?	Yes	No
Timing of need	Long term	Short term (drop ship)
Cost of items	High	Low

CHAPTER 4
PURCHASING

In many larger organizations, inventory and purchasing are separate units that may reside in the same department or in different departments. They can range in size from one individual to more than 100. In smaller organizations, one or two individuals may be responsible for performing both the inventory and purchasing roles. However the case, purchasing plays an important role in inventory performance. This chapter discusses the role and objectives of purchasing and presents the various purchasing methods that can be used to improve inventory performance.

4.1 ROLE OF PURCHASING

Just as the roles of inventory professionals have expanded over the years, so have the contributions made by purchasing departments. When inventory departments work closely with purchasing departments, vendor performance and on-time delivery increase, stockouts decrease, and savings potential increases. In traditional environments, purchasing departments have simply received requisitions for goods and services and placed orders. Today's best purchasing

departments work closely with inventory and maintenance departments to identify new products and technologies, provide input into the planning process for both maintenance and inventory, and actively work with vendors, contractors, and suppliers to positively affect quality, lead times, and other measures of performance.

4.2 PURCHASING AND INVENTORY PERFORMANCE

The primary purchasing objectives are to buy materials at the lowest responsive and responsible cost and to ensure adherence to purchasing terms and conditions. Maintaining continuity of supply and consistency of quality are also important objectives that go hand in hand with searching for new products and vendors and developing alternative supply sources. Meeting these purchasing objectives, as a means to improve inventory performance and maintenance productivity, requires teamwork among inventory, purchasing, and maintenance departments. Improving inventory performance can be accomplished by

- Reducing purchase cycle time, including lead times;
- Developing commodity expertise/specialization;
- Increasing the use of different purchase order types;
- Consolidating purchases;
- Increasing the use of volume discounts;
- Tightening control of purchase order terms and conditions;
- Qualifying vendors;
- Monitoring vendor performance;
- Searching for new products and vendors;
- Developing supplier relationships; and
- Working with vendors to reduce the incidence of past-due deliveries (that is, late shipments).

Other approaches to improving inventory performance require using different procurement methods, depending on such factors as the types of material or services purchased and whether the purchase is "small bid," one time, or repetitive.

4.3 DETERMINING HOW MUCH TO BUY

Determining how much to buy can be based on a variety of factors. For example, projections for buying inventory material can be based on material forecasts, inventory target levels, or the current amount of inventory in stock. Noninventory material requirements and some equipment requirements can be based on user demand forecasts. Capital material purchases and other equipment purchases are most often based on the agency's capital project schedule. Services are based on customer estimates, capital program requirements, past purchasing practices, and the quality of past services. Shipping schedules, market conditions, and industry practices like lot sizing and price breaks can also affect when and how much material must be ordered.

4.4 FORECASTING ANNUAL PROCUREMENT VOLUMES

Annual procurement volumes can be forecasted using a variety of methods and tools. Maintenance demand levels and patterns can be used to determine the types of material and services required. The timing of material orders depends on the size of the vendor pool and the vendor lead time. A large pool of vendors requires less advanced planning and ordering than a pool of one or two vendors. Similarly, ordering from vendors based in another country or who only have one or two manufacturing runs a year can also affect timing.

4.5 PURCHASING METHODS AND ORDER TYPES

The most common types of purchasing methods and orders are standard purchase orders, blanket purchase orders, annual or multiyear contracts, local purchase authorization, and purchasing cards. The following sections discuss each of these types, including the general use and the types of material generally purchased.

4.5.1 Standard Purchase Orders

Many transit agencies have used this type of purchasing method for most, if not all, of their purchasing activities. Standard purchase orders are most effectively used for one-time purchases or for material with low, sporadic usage. This type of purchase order can be used for one or more delivery locations, and the items listed on the purchase order may have varying prices. All terms are specific and known to both the buyer and the vendor.

4.5.2 Blanket Purchase Orders

Blanket purchase orders (BPOs) are useful when ordering items that are frequently used. They are usually limited to specific items or commodities, and the buyer must often commit to a minimum volume over a specific period (for example, a minimum quantity of 50 items over a 1- or 2-year period, with a not-to-exceed ceiling of 75 items). Depending on the item or commodity, a firm price, price range, or price formula is established when the BPO is initiated. The purchase is completed when the BPO is established. However, the actual delivery and invoicing are based on BPO releases prepared by authorized customers.

Blanket purchase orders can also be used to purchase a variety of items from a specific vendor, such as items from a local hardware store. Purchases may be limited to specific items or commodities. Pricing may be established from a vendor-provided catalog or price list, and the vendor often provides discounts.

Blankets are also commonly used to provide varying amounts of materials at different locations. The customer determines the amount and timing. For example, each storeroom may need different amounts of material at different times throughout the month, year, and so forth. The inventory or maintenance staff person calls the vendor and prepares the BPO release when the material reaches the reorder point. The vendor then delivers the material using the blanket order release. Each release for material draws money from the dollars committed to the BPO.

4.5.3 Annual or Multiyear Contracts

With annual contracts, the vendor is responsible for making scheduled deliveries at fixed intervals. Prices are fixed for each item, and delivery volumes are specified. The annual contract may include an option to modify the delivery volumes, timing, or locations throughout the life of the contract. Annual contracts are most often used with items and services that have a fairly constant usage, such as some types of filters, pest control, and uniform cleaning. As an example, an annual or multiyear contract can be established with a vendor to supply 40 filters to one storeroom, 85 filters to another storeroom, and 20 filters to a third storeroom every month.

These contracts can also be used for the delivery of vendor-held inventory. In this situation, the vendor maintains a backup supply of the material and is responsible for determining the timing of inventory replenishment and the quantity of material to be restocked. This type of annual contract is often used for frequently used items that have relatively low dollar value, such as nuts and bolts, small electrical hardware, and common household batteries. This type of material contract also uses firm prices for the material and has set inventory levels.

4.5.4 Local Purchase Authorization

Local purchase authorizations are used for small-dollar, direct-expense, generally noninventory purchases. They are controlled totally by the customer and work like checks in that they are used for one-time purchases.

4.5.5 Purchasing Cards

Purchasing cards are a relatively new mechanism for purchasing noninventory material. As with local purchase authorizations, purchasing cards are most effectively used for small-dollar, noninventory purchases.

CHAPTER 5
STOREHOUSE OPERATIONS

5.1 STOREHOUSE NETWORK

The size and location of storehouses depend on the size of the organization's fleet, the mix of vehicles, and the location of maintenance facilities. The storehouse network is generally configured on a centralized or decentralized basis. When only one storehouse is used or when one or more major storehouses supply several smaller storehouses, then the storehouse network is centralized. This network configuration is also called "hub and spoke" or "parent/child." When storehouses are supplied independently of one another, the network is decentralized.

Balancing centralization against decentralization primarily involves a trade-off between number of dollars invested in inventory and number invested in transportation costs. A lower amount of inventory is required when a central location is used to supply multiple maintenance facilities than when inventory is stored at each facility. However, the transportation cost to

deliver inventory from the central facility will normally be higher. The reduction in inventory can be projected using the following formula:

$$Q_n\left(\frac{\sqrt{n}}{n}\right)=Q_c$$

where:

Q_n = total inventory quantity required for n independent storerooms,
n = number of independent storerooms, and
Q_c = total inventory quantity required for a central warehouse.

For example, if 5 independent storerooms require 25 items each to meet demand (that is, 125 total), a central warehouse can meet the same demand with 56 items:

$$125\left(\frac{\sqrt{5}}{5}\right)=56$$

A centralized storehouse network can be more efficient and cost-effective for several other reasons. First, the incidence of separate ordering of the same material is reduced, thereby reducing ordering costs and avoiding overstocking of items. In addition, supervision and control is improved and personnel and space requirements are reduced.

Stores should be located as close as possible to where the material will be required on the basis of the amount of time customers are willing to wait for material from inventory. Most maintenance material is needed either immediately or by the next day, so maintenance material is usually in or adjacent to maintenance facilities. As a result, some combination of centralization and decentralization may be required. If the inventory system includes administrative materials and supplies, then a storeroom should be located so that the inventory is easily available to the customers.

5.2 STOREHOUSE LAYOUT

Storehouses are generally divided into zones on the basis of several factors, including

- Type or use of material (for example, engine parts, brake parts, and cleaning chemicals),
- Type of storage equipment (for example, drawers, shelves, and pallets),
- Special needs (for example, hazmat, temperature control, and high security),
- Usage (for example, fast moving and slow moving),
- Size of material, and
- Space availability.

Storehouse layout is determined by the mix of materials stored, the item sizes, and any special storage requirements (for example, requirements for hazardous material, controlled environment, and high-cost items). Fast-moving items may be stored in a more accessible

location so that they can be quickly retrieved by inventory clerks. Stores should be cost-efficient and provide for ease in changing configurations as the material requirements change. Today's storerooms have access to many different types of shelving, racks, and filing systems.

5.3 STOREROOM SECURITY

All parts, materials and supplies should be kept in secured storage areas. Access to the storage areas should be limited to authorized personnel. Secured and controlled access to storerooms and warehouses is necessary to monitor the physical movement and distribution of inventory. Secured storage facilities are also necessary to maintain accurate inventory records so that excess material can be reduced, project schedules can proceed on time, maintenance productivity is sustained, deliveries arrive on schedule, over-ordering is kept at a minimum, and vehicles are not held out of service because of lack of parts. In addition, maintaining accurate inventory records will lead to improved cost control. Secured and controlled access is also necessary to maintain orderly and effective housekeeping and will greatly reduce or eliminate problems with material shrinkage. When it is not practical or cost-effective to fully staff a storehouse with inventory personnel during all maintenance hours, specific storeroom tasks can be assigned to noninventory personnel (usually a maintenance supervisor). Although procedures may be streamlined, noninventory personnel should be held to the same performance standards regarding storeroom security and record keeping as inventory personnel.

5.4 PARTS STORAGE AND RELEASE

All additions to or deletions from inventory should be recorded, either manually or using an automated management information system. To ensure ease in locating a required inventory item and to ensure accuracy of inventory item counts, all inventory items should be assigned a unique identification number, usually referred to as a "stock" number. When a change is made to an item's form, fit, or function, a new number should be assigned.

Only designated personnel (including noninventory personnel during off-hours) should be authorized to choose parts from the secured storage area to fill a parts request. These individuals should ensure that all required approvals have been obtained before a part is released to the mechanic or other requesting individual. In addition, parts should not be released from the parts room without being recorded in the manual or automated inventory record and on a maintenance request or repair order. Recording the parts on the maintenance request or repair order will allow for the tracking of the part to a piece of equipment or location. This tracking will provide an audit trail and assist maintenance management in tracking repair costs by vehicle.

CHAPTER 6
PARTS MANAGEMENT

6.1 CATALOG

The parts catalog is a record, often organized by item class, of the materials parts and supplies available from inventory. Information provided for each item includes transit agency

part number, description, unit price, unit of measure, manufacturer cross-reference number(s), location, bin number, status, unit of issue, and specification number (if applicable). This information can be provided using either a computerized information management system or a hard copy.

6.2 INVENTORY INCLUSIONS/EXCLUSIONS

What types of items to include in inventory and how to value the items can vary, depending on the nature of the items and the strategy for control and distribution. The following are examples of the different types of items and the factors that influence control strategies.

- **Vehicle maintenance parts.** These parts are commonly used or hard to get and are usually included in inventory at average cost. Rarely used parts or parts that can be quickly procured and received may be excluded from inventory.
- **Facilities maintenance parts.** These parts are similar to vehicle maintenance parts, but more likely to be one of a kind for a specific facility, and fewer are stocked regularly.
- **Consumables (for example, grease and lubricants), shop supplies, cleaning chemicals, and janitorial supplies.** These materials may be included or excluded, depending on the cost and storage requirements. In addition, external janitorial vendors or vehicle-washing services may provide their own supplies.
- **Nuts, bolts, fasteners, and other general hardware.** These materials are usually provided in open bins in the maintenance shop as floor stock and are only kept in inventory in bulk because of their low unit cost. These items may also be excluded from inventory altogether, and an external vendor may be contracted to monitor and refill bins on the shop floor.
- **Repairable components.** There are many options for valuing, tracking, and controlling repairable components, depending on the purchase cost of the component, the cost of repair, the value of the "core" (or items awaiting repair), whether the items are repaired internally or by a vendor, dollar cut-offs for fixed-asset tracking, whether individual components are tracked (that is, serialized), and so forth.
- **Capital material.** Often, some accommodation must be made to meet regulatory and other tracking requirements for material purchased with capital funds.
- **Fuel and fluids.** These materials are usually controlled separately from other inventory because of the high overall dollar usage and investment, separate storage and control facilities, and, in some cases, separate automated support systems.

6.3 EXCESS AND OBSOLETE ITEMS

If the inventory contains many obsolete items, the inventory may be overvalued. Obsolescence is one of the components of inventory carrying cost. Too much excess inventory will increase the cost of the inventory, causing capital that would otherwise be used more productively to be unavailable. All excess and obsolete material should be eliminated from the inventory. Although the sale or disposal of excess or obsolete inventory may yield little financial benefit, other benefits will occur. These benefits include less time devoted to cycle counts or physical inventories; more free space for new, more useful material; and reduced valuation of the

inventory. As usage is tracked, slow-moving inventory should be highlighted. Obsolete or excess inventory can be identified in various ways, such as establishing a policy on the number of years, without issuing the material. Turnover, which is discussed in more detail in Chapter 8, can be used to track the effect of excess inventory.

CHAPTER 7
INVENTORY ACCOUNTING AND PHYSICAL CONTROL

7.1 MAINTAINING ACCURATE RECORDS AND VALUING INVENTORY

Accuracy of inventory records is necessary to

- Provide satisfactory customer service,
- Determine replenishment of individual items,
- Ensure that material availability meets repair or project demand,
- Analyze inventory levels, and
- Dispose of excess inventory.

There are several methods for valuing inventory.

- **FIFO, or first-in/first out**. The oldest (or first received) material on hand for a given item is used to value that item. With the FIFO method, material tends to be undervalued when prices rise. This technique is primarily used for high-turnover items, typically to maximize dollars.
- **LIFO, or last in/first out**. The most recent addition to the inventory is used to value that item. In this case, the price used for the item may overvalue material when prices rise. This method is also typically used in the manufacturing industry to minimize dollars and reduce taxes.
- **Average cost**. The cost of all material taken into inventory is continually averaged so that the item cost reflects both the oldest and the newest material. This method is used for operating material in both manufacturing and maintenance environments. One variation of average cost is *storeroom average cost.* With this method, inventory average costs are calculated for individual storehouses.
- **Order-specific cost**. Order-specific costs are maintained on an item-by-item or per-shipment basis. This method is commonly used when the requirement exists to maintain an audit of actual costs. Capital material is often tracked by this method.
- **Standard cost**. A fixed cost, or "standard cost," is established for an item for a period (for example, 1 year), and all inventory transactions for the item during the period are valued at the same standard cost. Adjustments are made at the end of the period to balance inventory value with actual dollars spent. This method is sometimes used for repaired or rebuilt components.

The "average cost" method is the valuation method most frequently used in the transit industry for the normal types of material kept in the inventory. The method is also used to value repaired or rebuilt components, but the "standard cost" method is also an option. If capital

material is included as part of the inventory or tracked via the inventory system for accounting purposes, the "order-specific" method is appropriate.

7.2 CYCLE COUNTING

Cycle counting entails periodic counts of inventory items based on the ABC principle described in Section 3.2.1. (That is, A items are those with the greatest annual dollar usage, or the high-value items; B items are those with a lesser amount of annual dollar usage, or the medium-value items; and C items are those with the lowest annual dollar usage, or the low-value items.) Cycle counts are conducted periodically throughout the year to verify the accuracy of inventory records and value.

Cycle counts for A items, which account for approximately 10-20 percent of all items in the inventory (and 70 percent of the total annual inventory usage dollars), should be conducted monthly or quarterly. B items, which account for approximately 30 percent of all items in the inventory (and approximately 20 percent of the total annual inventory usage dollars), are normally counted quarterly to semiannually. C items, which account for about 50-60 percent of all inventory items (and 10 percent of the total annual inventory usage dollars), are counted semiannually to annually.

Implementing a cycle-counting program can eliminate the need to conduct an annual physical inventory. Advantages are that interruption of daily business activities will be eliminated and management will receive more accurate counts of inventory availability throughout the year. In addition, the normal discrepancies that can occur when tracking inventory can be corrected earlier and have less effect on customer service. An essential factor in the cycle-counting program is to focus on correcting the *cause* of the discrepancies, not just adjusting computer inventory balances. Of cycle-count discrepancies that can be corrected, examples of potential causes include

- Inadequate storage space,
- Items not stored in an orderly manner,
- Improperly identified items,
- Uncontrolled access to storage area,
- Improperly planned locations,
- Ineffective item-locator system,
- Unseparated usable and unusable inventory,
- Transactions reported in an inaccurate and untimely manner, and
- Vaguely defined responsibilities.

Table 10 shows general categories of cycle-counting errors.

TABLE 10 Categories of cycle-counting errors

Error Factors	***Shortage of Material***	***Overage of Material***
Counting Error	Counted incorrectly; didn't count all locations	Counted incorrectly
Recording Error (Records)	Missed or incorrect data input	Missed or incorrect data input
Identification Error	Item identified incorrectly -- not counted under correct number	Item identified incorrectly -- another item included in count
Physical Control	Unauthorized or unrecorded removal	Unauthorized or unrecorded recovery

The appendix provides a sample cycle-count form.

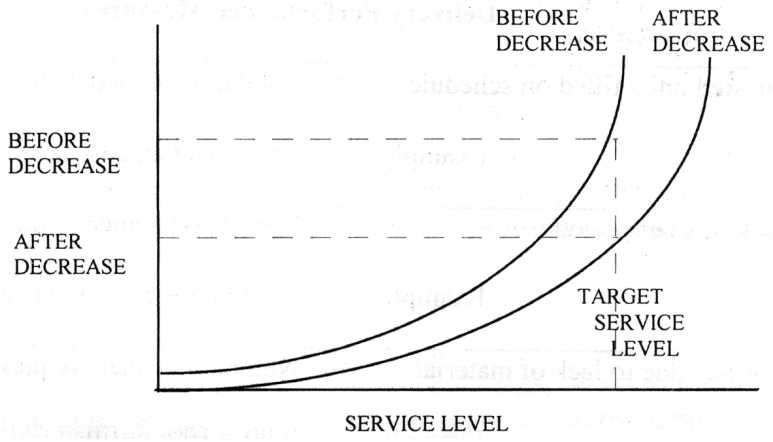
7.3 PHYSICAL INVENTORIES

Physical inventories are used less frequently today than cycle counting is. Generally, physical inventories are conducted annually for all items in the inventory. As a result, problems with the inventory are not corrected until the count is done, typically at the end of the fiscal year. In addition, conducting an annual physical inventory often requires bringing in extra help because the inventory function will need to be closed until the count is completed, a process that can take several days depending on the inventory size and the number of inventory locations. This requirement, in turn, requires that all transactions be suspended until the count is completed and the records verified. The result of the annual physical inventory may require a large financial adjustment at the end of the year if items are out of balance.

CHAPTER 8
EVALUATING THE INVENTORY MANAGEMENT FUNCTION

As discussed earlier, the objective of inventory management is to meet service level targets with minimum inventory investment. Figure 11 illustrates this concept. As shown, with the service level target constant, a decrease in inventory investment can achieve the same level of service.

Figure 11 Service Level Before and After a Decrease in Inventory Dollars Invested



Top management focus on these conflicting objectives is essential in evaluating inventory performance. The following sections discuss the methods available for measuring how well these objectives are being met.

8.1 PERFORMANCE MEASURES AND INDICATORS

The total costs of inventory are

- Preparation costs (including planning and ordering),
- Transportation costs (including receiving and distribution),
- Carrying costs (including capital, storage [for example, handling, security, space, and records], obsolescence, pilferage, and deterioration), and
- Stockout costs (including back orders [for example, record keeping, emergency procedures, and missed or late service runs]).

8.1.1 Customer Service

Customer service can be defined as providing material when the customer needs it. The customer can be either a user of material or another storehouse. To satisfy the objective of providing material when the customer needs it, it is necessary to obtain a target level of customer service for

- Material requests,
- Project schedules, and
- Back orders (that is, stockouts).

Measures of customer service include initial delivery performance and back order, or stockout, resolution performance.

Table 11 shows examples of measures for determining customer service levels.

TABLE 11 Examples of measures for determining customer service levels

Delivery Performance Measures		
% of total requested units filled on schedule	=	Total units issued/Total units requested
Example:		15 issued / 20 requested = 75% filled on schedule
Number of stockouts per period	=	New zero balances/Time period
Example:		5/Month = 5 stockouts per month
% of unfilled orders due to lack of material	=	Number of orders requested/Number of orders unfilled
Example:		9/90 = 10% unfilled orders
% of user requested line items filled from inventory	=	Number of line items filled/Number of line items requested
Example:		72/78 = 92% item requests filled
Average number of vehicles held out-of-service for parts per day	=	Number of vehicles held/Number of service days
Example:		15 vehicles/20 days = .75 vehicles per day
% of maintenance hours lost while waiting for parts	=	Nonproductive mechanic hours/Available mechanic hours
Example:		14 nonproductive hours/192 available hours = 7% maintenance hours lost
Back order (Stockout) Resolution Performance Measures		
Number of days out of stock	=	Date received – Date of stockout
Example:		June 20-July 7 = 13 days
Average time to fill back orders	=	Total number of days to fill all back orders/Total number of back orders
Example:		432 Days/65 back orders = 6.65 days per back order

If the computer system does not provide the data required to calculate the performance measures, the data can be easily sampled using a simple form at the stockroom window that records

- Date requested,
- Quantity requested,
- Quantity filled,
- Date filled, and
- Bus held (yes/no).

The appendix provides a sample of this form. Data on mechanic time must be provided by a maintenance work order system.

8.1.1.1 Initial Material Delivery Performance

Initial material delivery performance can be defined in terms of the following:

- Percentage of the following that are filled on schedule: requests, line items requested, and total units requested.
- Number of the following: periods without a stockout, operating days without a stockout, stockouts per period, idle work hours resulting from a stockout, and vehicles out of service.

8.1.1.2 Back Order (Stockout) Resolution Performance

Stockouts may be defined as situations in which there are zero items in inventory, no items available when requested, no items available when work starts, or a number of open orders. Whichever definition is used, it should be consistent. High stockouts (and low inventory investment) may be a desirable result of other effective inventory management decisions relating to "just-in-time" inventory supply.

Back order, or stockout, resolution performance can be defined in terms of the following:

- Aging of back ordered material requests,
- Percentage of back ordered material requests filled within specific time periods, and
- Number of days out of stock.

8.1.2 Inventory Investment

Factors affecting inventory investment include

- Nature of inventory material (including breakdown maintenance parts, project inventory, and preventive maintenance parts) and
- Service-level objectives.

One method for measuring inventory investment involves looking at *inventory value* (that is, total inventory dollars). The formula for this way of measuring inventory investment is

$$\text{Inventory Investment} = (\text{Units On Hand}) \times (\text{Average Price})$$

Measuring the total inventory investment dollars involves looking at the total capital investment in inventory parts, materials, and supplies.

Inventory turnover rate (ITR) is a second method for measuring inventory investment. ITR can be calculated as follows:

$$\text{ITR} = \frac{\text{Annual Usage Dollars}}{\text{Total Inventory Dollars}}$$

The inventory turnover rate measures the number of times per year that the material available for use at the beginning of the year has been used.

A third method for measuring inventory investment is *time period coverage* (that is, looking at the number of months on hand). The formula for measuring months on hand is

$$\text{Months on hand} = \frac{\text{Total Inventory Dollars}}{\text{Average Monthly Usage Dollars}}$$

Months on hand is used to determine how long the material in the inventory will last, given the same amount of usage averaged over a specified period of time.

Table 12 presents examples of the measures of inventory investment.

TABLE 12 Examples of measures for inventory investment

	Annual Usage	**Inventory Value**	**Inventory Turnover Rate (ITR)**	**Months On Hand**
Part Number Analysis				
123-1234-5 Brake Shoes	$ 84,643	$ 72,446	1.17	10.27
Location Analysis				
Elm Street Maintenance	$ 72,616	$136,562	0.53	22.6
Oak Street Maintenance	$ 108,572	$ 64,887	1.67	7.17
TOTAL INVENTORY	$978,769	$776,962	1.26	9.53

8.1.3 Inventory Accuracy

Measuring inventory accuracy involves looking at the degree to which computer records match actual inventory quantities on hand. The primary performance measures look at (1) the percent of inventory items for which the actual quantity on hand matches the computer balance (that is, the percent of accurate balances); and (2) the percent of absolute dollar variance of inventory balance discrepancies. These performance measures are calculated as follows:

$$\text{Percent accurate balances} = \frac{\text{Number of items (that is, part numbers) that match}}{\text{Total number of items counted}} \times 100$$

$$\text{Percent absolute dollar variance} = \frac{\Sigma \text{ absolute (computer value - value of actual counts)}}{\text{Total computer value of items counted}} \times 100$$

Table 13 shows sample item counts.

TABLE 13 Sample item counts

Item number	Unit cost	Computer balance	Actual count	Difference	$ Difference
Item 1	$ 5.00	2	2	0	$0.00
Item 2	$15.00	4	3	1	$15.00
Item 3	$ 2.75	7	8	-1	-$2.75
Item 4	$ 1.00	1	1	0	$0.00
Item 5	$ .15	9	9	0	$0.00

The percent of accurate balances = 60 percent, because counts match for three of the five items. The absolute dollar variance of the items counted is $17.75. (The absolute dollar variance is calculated by adding all absolute dollar differences regardless of whether the count was over or under.) To compute the total computer value of the items counted, first multiply the unit cost of each item with the item's corresponding computer balance. Then, add the values of the resulting products. In this example, the total computer value is $91.60. So, the percent of absolute dollar variance is $17.75 divided by $91.60, or 19.4%.

8.2 BENCHMARKS

Table 14 presents benchmark values for inventory performance indicators. These values are based on responses from a survey of the 300-plus public transit systems that were members of the American Public Transit Association (APTA) during calendar years 1993 and 1994.

Rather than using the average value alone as the benchmark value, the following are presented for each inventory performance indicator:

- Mean (that is, the average value),
- Median (that is, the middle value, which has an equal number of respondents above and below),
- Maximum (that is, the highest value),
- Minimum (that is, the lowest value),
- 20th percentile (that is, the value greater than 20 percent of the responses), and
- 80th percentile (that is, the value greater than 80 percent of the responses).

TABLE 14 Benchmark values for inventory performance indicators

Performance Indicator	Mean	Median	Max	Min	20%	80%
Bus inventory turnover	1.74	1.43	7.36	0.13	0.75	2.54
Rail inventory turnover	0.71	0.56	1.43	0.29	0.51	0.99
Stockout % of SKUs	1.52%	0.17%	20.0%	.013%	.047%	1.54%
Bus inventory $/vehicle	$5,027	$4,604	$15,384	$281	$2,566	$7,234
Rail inventory $/vehicle	$37,498	$27,418	$139,286	$6,785	$12,660	$47,688
% Items out of balance	7.83%	5.0%	60%	.005%	1.42%	10%
Bus % fill rate	89.0%	95.0%	100%	10%	85%	98%
Rail % fill rate	86.1%	90.2%	100%	40%	84.4%	98.3%
Bus % obsolete items	9.2%	5%	60%	.01%	2%	13.8%
Rail % obsolete items	6.1%	5%	20%	1%	1.12%	10%
Bus days to fill back order	16.4	10	90	1	3	30
Rail days to fill back order	25.3	18	56	1	14	45
Inventory $ per person	$217,980	$146,000	$1,300,000	$32,418	$84,302	$250,578
Person $/Inventory $	$0.31	$0.25	$1.05	$0.05	$0.15	$0.44
Transactions per person	181.8	138.5	798	5	61.1	225.6

8.3 "REAL-WORLD" FACTORS AFFECTING INVENTORY PERFORMANCE

Inventory management performance results from a complex interaction among several factors, including inventory attributes, management decisions, policies, and practices. When applying inventory in real-world conditions, several hidden factors may affect inventory performance, including

- The degree to which executive management focuses on inventory performance goals and on the perceived importance of inventory management,
- The data available from computer systems,
- The capability to accurately measure inventory performance indicators,
- The ratio of staff time spent performing inventory management functions versus performing and controlling daily inventory transactions,
- The reasons and strategy behind configuring a storehouse network,
- The extent to which multiple replenishment methods are fully used and effectively matched to the types of demand for an item,
- The types of items included in or excluded from inventory,
- The way inventory is valued,
- The classifications used for managing inventory items,
- The level of joint planning between inventory and maintenance personnel,
- The extent to which multiple procurement methods are used,
- The level of discipline associated with record keeping during noncovered storehouse hours,
- The focus of the cycle-counting program on correcting the cause of errors,
- The level of inventory responsibility assigned to noninventory personnel, and
- The number of inventory tasks not assigned.

8.4 SUMMARY

As stated throughout this handbook, materials professionals are continually challenged to provide maximum parts availability and keep inventory investment low. The objective of this handbook is to provide a framework for transit managers and staff to better understand, evaluate, and manage inventory. Because of the wide variance in the size of transit agencies and in the services provided, the information presented should be used only as a *framework* for improving inventory management and customer service. The techniques and methods described should be adapted on the basis of the size of the operation, the types of material stored in inventory, and the management tools available.

The indicators in this chapter can be used to monitor and evaluate inventory management performance. The benchmark values for the indicators can serve as a yardstick for comparing inventory management performance internally across years, across storage locations, or between different departments or divisions.

APPENDIX: SAMPLE FORMS

Issue Ticket-Sampling Form

Date: _____

Storeroom	Item No.	Item Description	Quantity Requested	Quantity Issued

Inventory Item Cycle-Count Form

Date: ____________________________

Item No.	Computer Balance	Count	Item Unit Cost