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A Desk Guide for Inventory Managers in the Transit Industry

This TCRP digest provides the results of TCRP Project E-3, "Desk Guide for Inventory Managers in the Transit Industry," conducted by Susan Thomas and Michael Kilpatrick. The digest summarizes inventory control techniques appropriate to the transit industry, decision-making techniques, and benchmark references The final report, which describes the analyses and case studies performed during the course of the project, is available as TCRP Web Document 4 on the Internet at www2.nas.edu/trbcrp.

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The objective of the Inventory Management Desk Guide is to provide a readily usable reference guide to assist transit managers and staff to better understand, evaluate, and manage inventory. This Desk Guide summarizes inventory control techniques appropriate to the transit industry, decision-making techniques, and benchmark references. Because of the wide variance in the size of transit agencies and the services provided, the information presented in this Desk Guide should be construed as a framework for improving inventory management and customer service. Techniques adapted should be based on the size of the operation, types of material stored in inventory, and the management tools available.

As a result of the concepts and techniques discussed in this Desk Guide, inventory managers will

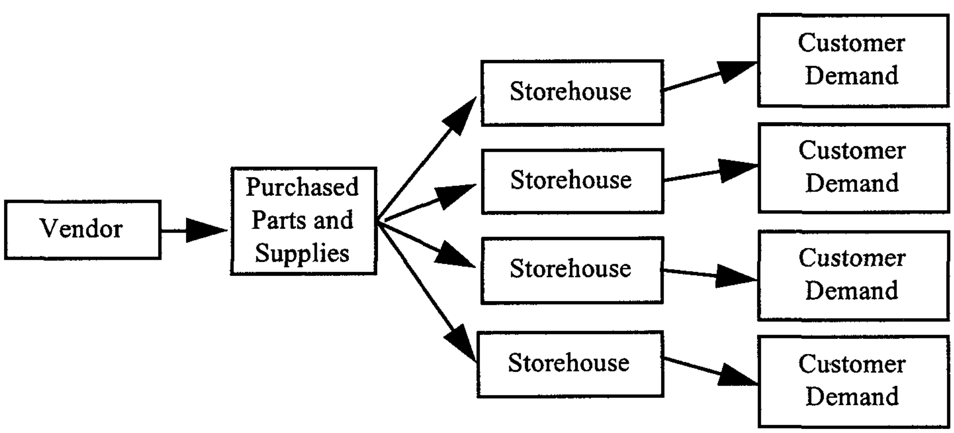
- Gain an in-depth understanding of basic inventory management concepts
- Learn to apply these concepts to real life situations
- Understand the impact and consequences of inventory management actions
- Understand the interrelationships among inventory management staff, customers, and other departments within the• transit organization
- Provide improved service to customers
- Communicate more effectively

1. MANAGING INVENTORY--AN OVERVIEW

Materials managers have always been faced with dealing with the two conflicting objectives of inventory management, namely, to provide maximum parts availability while keeping inventory investment low. 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 production efficiency, public sector organizations, including public transit agencies, have also begun to focus on improving the management of their inventories.

As shown in Figure 1, storehouse and inventory requirements are driven by customer demand--that is, the parts, materials, and supplies needed by users (hereafter referred to as customers) to perform the day-to-day activities required by the business. Material requirements include such diverse items as vehicle (bus, rail, inclined plane, trolley, etc.) parts; infrastructure (guideway systems, track, bridges, etc.) materials; office supplies, and janitorial maintenance supplies. As parts and materials are requested from the storehouse, new orders are generated by purchasing to replenish inventories.

Fig. 1 Inventories and the Flow of Materials



In the remainder of the Desk Guide, the researchers discuss in more detail the goals and objectives of inventory management; the impact of customer demand on the operation of the inventory function; and the techniques available to improve customer service while controlling the dollars invested in inventory.

1.1. Inventory Management Goals and Objectives

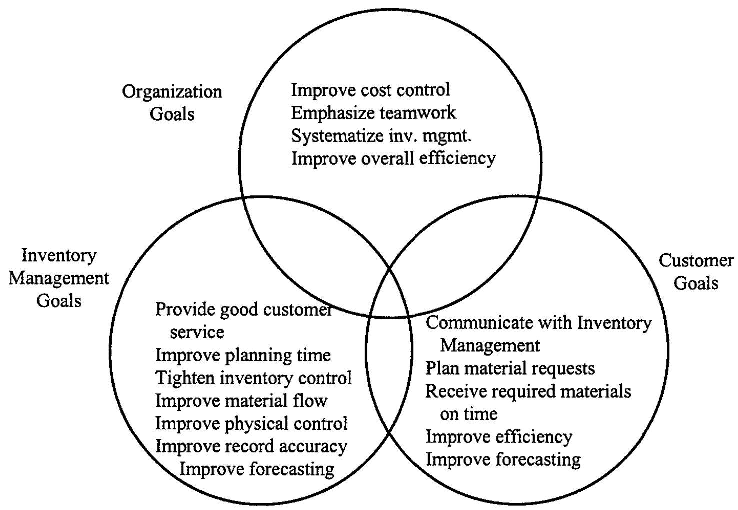
The overall goal of inventory management is to provide the right item, at the right location, at the right time, at the best cost. To meet this goal, transit providers must also work with two major objectives in mind:

1. Maximizing customer service, i.e., providing material when the customer needs it; and

2. Minimizing inventory investment, i.e., controlling the dollars invested in parts and material.

The objective of maximizing customer service is closely related to the goals of the customer or user department. Similarly, the objective of minimizing inventory investment is closely aligned with the goals of the overall organization. Figure 2 illustrates this close relationship.

Fig. 2 Inventory Management Partnership



The goals and objectives of inventory management as well as those of the organization and customer can be accomplished through the following:

- Eliminating redundant tasks
- Reducing recordkeeping errors
- Simplifying or minimizing paperwork
- Defining authority and responsibilities
- Improving storehouse network and physical layouts
- Reducing stockouts
- Reducing excess and obsolete inventory
- Reducing administrative lead time
- Consolidating stocking locations
- Maintaining accurate inventory balances
- Reducing in-service failures due to improper material substitutions

1.2. Functions of Inventory

Inventory serves as a buffer between the following:

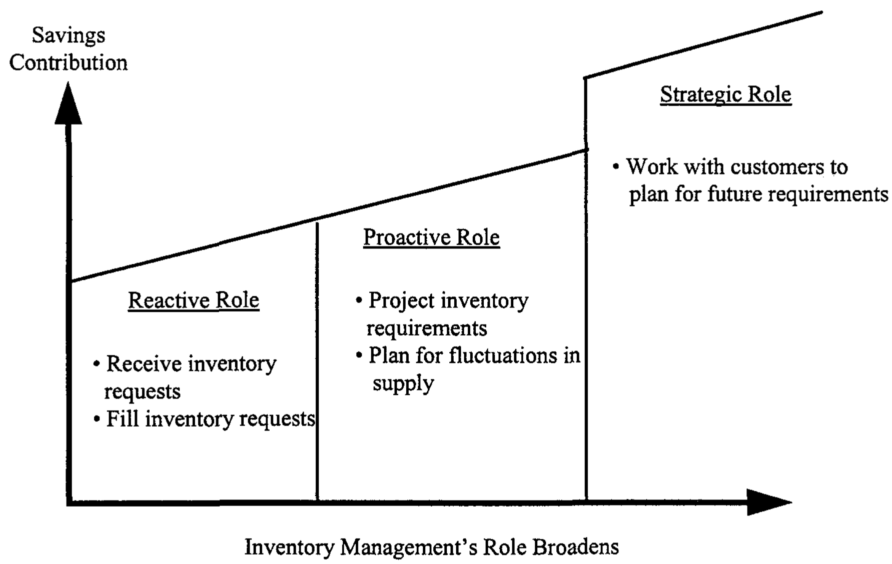
Customer requirements	and	Maintenance parts purchase
Internal repair projects	and	Component availability
Capital project requirements	and	The suppliers of material
The customer	and	Fluctuating prices
The customer's geographic location	and	Geographic location of the storehouse

As a result, inventory management becomes responsible for

- Anticipating requirements
- Maintaining critical parts on hand
- Providing a hedge against unfavorable market conditions
- Minimizing fluctuations in demand and supply
- Responding to requirements for geographic dispersion

Figure 3 shows the evolution of the inventory management function.

Fig. 3 Evolution of the Inventory Management Function



As shown in Figure 3, as inventory management organizations mature from a "reactive" role (responding only at the point of a customer request) to a "proactive" role (anticipating customer requirements) to a "strategic" role, savings contributions rise. This is because organizations operating in a reactive role do not anticipate customer requests and are often forced to either overstock material or waste time and money expediting shipments. Inventory management organizations operating in a proactive mode are able to project inventory requirements for the near term and do some planning for possible fluctuations in supply and demand. However, inventory management organizations operating strategically are often able to project inventory requirements over several years and will plan for the increase or decrease in inventory stock accordingly.

2. INVENTORY MANAGEMENT ORGANIZATION

Depending on the size of the transit organization, the inventory management function may be located at the department or division level. It may be a stand-alone function or part of another area such as maintenance or accounting. This section discusses the *general* duties and responsibilities of inventory management. Of course, the requirements of a particular organization will determine the exact placement of these responsibilities within the organization's structure. However, the basic responsibilities for inventory management, stores, and material planning are presented below.

Management

- Establishing centralized decision making and issue resolution
- Ensuring constant adherence to inventory management policies and procedures
- Planning materials requirements on the basis of user forecasts and monitoring usage against the plan
- Monitoring the effectiveness and cost-efficiency of inventory activities
- Implementing systems that accurately track accounting expenditures

Stores

- Providing physical security and safekeeping of material
- Maintaining accurate inventory records
- Maintaining physical layout of storehouses including bin location assignments
- Monitoring physical movement and distribution of material throughout the organization
- Receiving and storing material
- Issuing stock material in response to a material request from users
- Conducting cycle counts of stock material
- Developing a facilities plan to reduce stocking locations

Material Planning

- Replenishing stock items and determining appropriate replenishment methods
- Classifying or stratifying stock material into classes such as the ABC system of inventory control (discussed in Section 3)
- Making sure material is on-hand when needed
- Determining where material is stocked and how much material is stocked (including storehouse locations and remote sites)
- Projecting material demand
- Making the decision of stock versus non-stock items
- Maintaining the catalog

Customers also have responsibility for working with inventory management to ensure that good inventory management practices are implemented and followed. These responsibilities include the following:

- Following procedures regarding authorization
- Writing all material specifications
- Completing purchase requisitions for non-stock material
- Determining material needs and schedules
- Identifying "must-have" material at remote sites
- Providing quality feedback to inventory management on its level of service

3. INVENTORY DECISIONS

Inventory decisions usually occur at three levels: the management or policy level, the intermediate level, and the individual inventory item level. As shown below, the three levels move from establishing overall goals, to determining how the goals will be implemented, to working with individual inventory items.

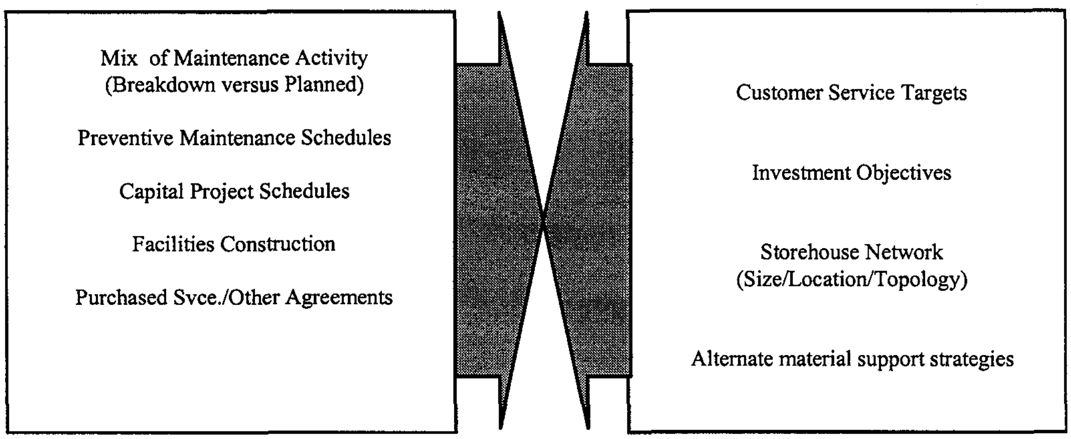
3.1. Policy Decisions

Management- or policy-level decisions are generally made by the individual who has overall responsibility for the direction of the inventory management function. Decision making at this level focuses on the following:

- Setting overall customer service/inventory investment goals
- Developing inventory strategies for user (or customer) support
- Determining the most cost-effective strategy for consolidating and distributing inventory

Figure 4 shows how customer requirements for inventory material can affect inventory policy.

Fig. 4 The Role of Customers in Policy Decisions



3.1.1 Customer Service Goals

Service goals are established to provide inventory managers with a means for measuring the level of service provided by inventory management to its customers. A target is established, such as 95 percent, for the number of times a material request is made and filled *at the time of the request (and to provide stockouts within [time]).* That is, the inventory management function should strive to fill material request orders 95 percent of the time. Section 7 discusses the specific measures of customer service available to inventory managers.

3 1.2. Investment Goals

Inventory investment goals focus on the total value of the inventory and the average 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. Specific measures of inventory investments are also discussed in Section 7.

3 1.3. Inventory Support Strategy

Inventory managers are also responsible for developing strategies for the effective and efficient provision of inventory material. Such strategies may include the type of storehouse network (parent/child or wholesale/retail, hub and spoke, independent storehouses); decisions regarding the inclusion or exclusion of capital material; and use of consignment and vendor maintained inventory.

3 1.4. Distribution/Consolidation Strategy

Strategies for determining how material should be physically stored and distributed to customers is dependent 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 require the transfer of material between storehouses and the pick-up and delivery of material to many sites. Smaller operations may use only one storehouse that supplies all material for the property.

3.2. Intermediate Inventory Decisions

Intermediate inventory decisions focus on implementing the strategies developed at the policy level. Intermediate decisions focus on such activities as:

- Grouping items by ABC classifications
- Using commodity classes to control inventory decision making

3.2.1. Stratifying Inventory Using the ABC Principle

Inventory items should be stratified, or grouped, so that the focus is on the most important items. This approach will prevent dollars from being tied up in items that are sitting idle and alleviate the risk running out of critical parts. Using ABC analysis is one approach that is both easy to understand and to implement. Stratifying inventory using the ABC approach will

- Improve overall material availability while reducing excess and obsolete material
- Focus on material that has the highest dollar impact
- Minimize the probability and severity of stockouts
- Effectively utilize inventory management staff time

The ABC principle is to "control the vital few." An ABC analysis of inventory involves

1. Establishing levels of importance such as A, B, and C (or as many classes as are warranted) based on the items' characteristics

2. Classifying each item on the basis of the criteria established

3. Applying a degree of control in proportion to the importance of 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; and "C" items are those with the lowest annual dollar usage and often the least value. Characteristics of the ABC principle are shown on the following page.

A Items	Highest annual dollar usage items	Accounts for about 70% of the total annual inventory usage dollars. Approximately 10% to 20% of all items in the inventory can 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 be classified as A items.
C Items	Lowest annual dollar usage items	Accounts for about 10% of the total annual inventory usage dollars. Approximately 50% of all items in the inventory can be classified as A items.

In addition to annual dollar usage, factors affecting the importance (or classification) of an item include the following:

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

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 operation and the total inventory value.)

1. Classify items by annual dollar usage:

Greater than $50,000	A item
Between $5,000 and $49,999	B item
Less than $4,999	C item

2. Adjust individual items based on other criteria:

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 class

As shown below, each of the ABC classes requires different levels of control. For example, because A items are responsible for the greatest annual dollar usage or have any of the factors identified above, these items require the greatest degree of control. B items, due to their lesser importance, have a lower degree of control; and C items require the least control.

<u>Control of A Items</u>

- Monthly evaluation of forecasts and the forecasting method
- Frequent, perhaps monthly, cycle counting with tight tolerances on accuracy
- Daily updating of records
- Frequent review of demand requirements, order quantities, and safety stock; usually results in relatively small order quantities
- Close follow-up and expediting to reduce lead time

<u>Control of B Items</u>

- Similar to controls for A items, but control activities take place less frequently

<u>Control of C Items</u>

- The basic rule is to "have them on-hand"
- Simple or no records, perhaps use a periodic review of physical inventory or a two-bin system
- Large order quantities and safety stock
- Store in areas readily available to users or storekeepers or may be floor stock
- Count items infrequently, annually or semiannually, with scale accuracy (weighing rather than counting) acceptable

Examples of control by ABC classification are shown in the table below.

Inventory Tasks	**A Items**	**B Items**	**C Items**
Estimating demand	Each item	% change by commodity	By exception
Cycle counting	Once per quarter	Once per 6 months	Once 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

The following table presents an example of item rankings in descending order by percentage of annual dollar usage. Classes are assigned based on each item's annual dollar usage. While the cut-off between the different classes is somewhat arbitrary (but based on the 70-20-10 rule), these items show a distinct value differential between items 4 and 5 and items 9 and 10.

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

The second step in this process is to reorder the items, grouping them by ABC classification. As can be seen, the general rules presented above for applying ABC classification apply in this case. Once the classes are defined, controls should be put in place to monitor performance.

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

Once the preliminary ABC analysis has been completed, it is a good idea to get the customer's (user's) input. His or her role in ABC analysis is to review the preliminary ABC breakdown with material planning. Input should be provided on projected usage, expected changes in usage amount and/or pattern, cost of a stockout (item criticality), and other information, as available.

3.2.2. Control Through Using Commodity Classes

The commodity class principle is to group like commodities into classes and subclasses to improve control. Benefits of using commodity classes include

- Easier identification of items
- Grouped analysis of item information (lead times, usage, etc.)
- Combined replenishment methods
- 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 inventory classes for rolling stock include

xxxx Buses
xxx Brake, steering, axle and wheel components
xxx Cab, body and frame structural components
xxx Seats
xxx Heaters

xxxx Rail equipment
xxx Braking systems
xxx Controls
xxx Power systems
xxx Right-of-way

xxxx Chemicals
xxx Absorbents
xxx Bus wash chemicals
xxx Degreasers

3.3. Item-Level Decisions

Decision making at the inventory item level focuses on

- Forecasting demand
- Determining replenishment levels
- Determining stocking points

Individual item inventory forecasting and replenishment decisions focus on (1) how much to order and (2) 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 demand levels and patterns, vendor pool, vendor lead time, industry practices (lot sizes, price breaks, etc.), shipping schedules, market conditions, and funding/budget level constraints.

3.3.1. Forecasting Demand

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

The purpose of establishing an inventory and forecasting demand is to

1. Cover fluctuations in supply and demand

2. Accumulate stock in advance of demand

This is done to assure the availability of material by accurately forecasting material requirements, i.e., determining what items should be ordered, when they should be ordered, how they should be ordered, and in what quantities.

Good forecasting requires recognition of the two conflicting inventory management objectives discussed earlier--to maintain a high level of customer satisfaction but at the same time minimize inventory investment (the amount of dollars tied up in inventory). Too many times there is a tendency to over-stock in order to satisfy the first goal or under-stock to satisfy the second!

It is also necessary to focus on forecasting demand for the right things--for example, why do we often spend the same amount of time forecasting for such low cost/high volume items as nuts and bolts as we do such items as traction motors and brake shoes? Do we really need to track certain items at all? Or only at a gross level? Can we set out items like common nuts and bolts in bins and refill the bins as they get low, not worrying about charges on a per item basis? Decisions such as these can be made easier by applying the principles of ABC analysis and commodity classifications.

It is also important to recognize that different methods should be used to forecast requirements for different types of material. In other words, "like" 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 various types of materials.

Most inventories in the transit industry are composed of two broad categories of materials: The first category includes materials where demand is based on regular or scheduled usage patterns. This category applies to

-- Project materials where demand is dependent on the project schedule

-- Routine maintenance parts for repair work done on a scheduled basis (30,000-mile replacement, 2-year check, etc.)

-- Routine work with a scheduled frequency (overhauls, rehabs)

-- Supplies where demand is based on regular or scheduled activities, e.g., standard office supplies and janitorial and safety items

The second broad category of materials are those that are used on a random basis as breakdowns occur or repairs are needed. This category applies to

-- Parts, including many consumable or repairable items (those replaced and discarded or repaired for later use), and critical items (those that require 100 % availability)

-- Breakdown maintenance items

-- Routine work never done before (order for new and different buses or locomotives)

-- Materials used for facilities maintenance

3.3.1.1. Types of Demand

There are many forecasting methods available based on the types of materials stocked in inventory. Generally, demand is looked at in one of two ways:

Dependent demand where material requirements are determined by user decisions.

Capital Projects Planned Maintenance	⇨	Calculated Requirements

Independent demand where material requirements are determined by uncontrolled factors.

Unscheduled maintenance	⇨	Forecasted Requirements

3.3.2. Determining Replenishment on the Basis of Demand

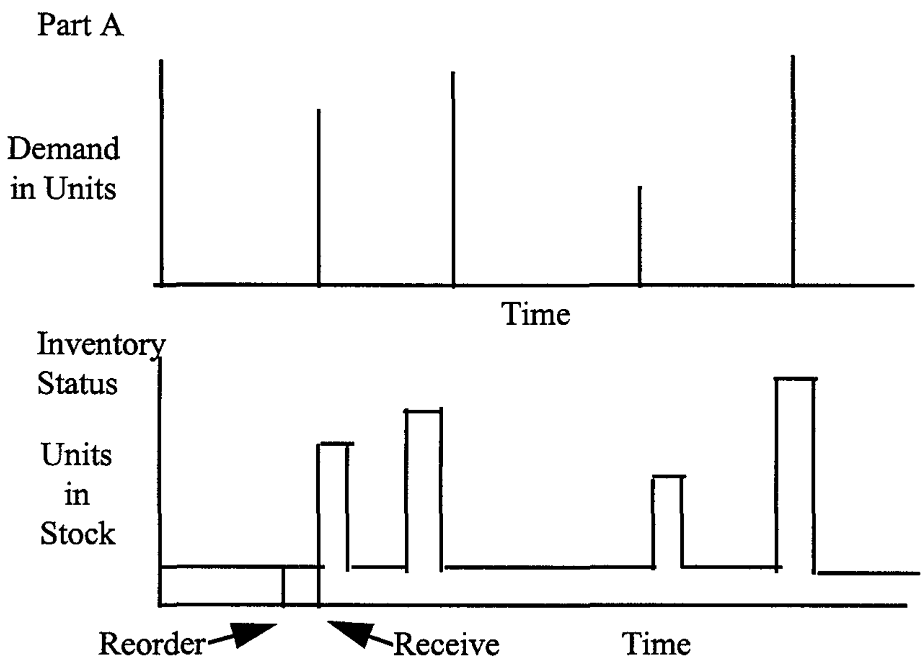
As shown in the table below, there are basically three types of demand that are of concern to inventory managers:

Dependent Demand	Capital projects Planned maintenance (Calculated requirements)	⇨	Fixed Schedule Fixed Order
Intermittent Independent Demand	Unscheduled maintenance (Forecasted requirements)	⇨	Reorder Point/EOQ Min/Max
Stable Independent Demand	Unscheduled maintenance (Forecasted requirements)	⇨	Fixed Period

Where material requirements are determined by user decisions, *dependent demand,* the demand is generally known. 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, it is easy to calculate what the majority of the material requirements will be. An appropriate method for ordering material on the basis of dependent demand with scheduled usage would be the fixed schedule. In this case, the exact amount and type of material required is known and delivery can be scheduled for specific dates and locations.

Figure 5 schematically depicts the relationships between demand and inventory stock status, reorders and receipts, and timing.

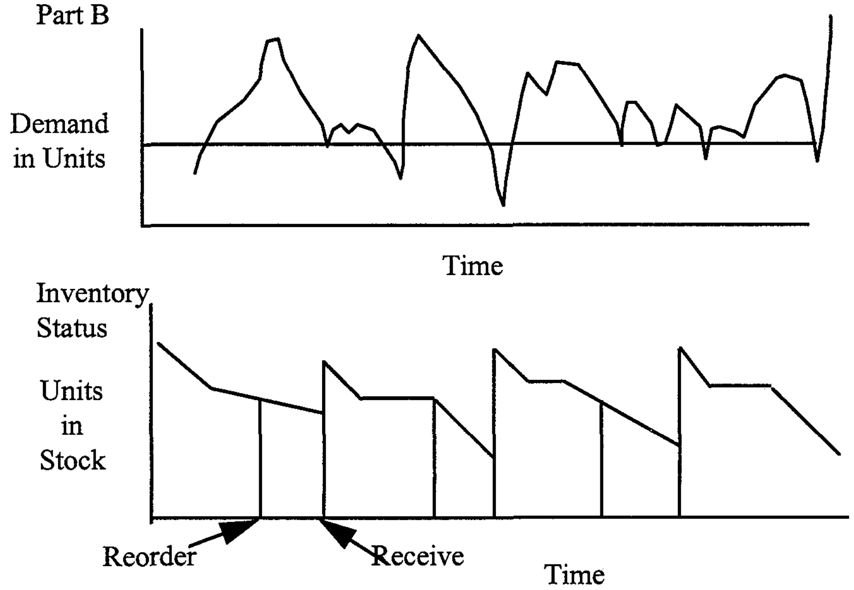
Fig. 5 Dependent Demand



The second type of demand, *independent demand,* is determined by uncontrolled factors This type of demand includes unscheduled maintenance or other activities where material requirements can not be forested in advance. Because the exact frequency and timing of breakdowns or unscheduled repairs can not be known in advance, forecasting for this type of material must be done in a different manner than for scheduled material requirements. For items where usage can not be easily projected because of irregular demand patterns (and this is often the case in the transit industry), some other method for determining stocking quantities must be applied, such as reorder point/economic order quantity (EOQ), min/max, fixed schedule, order up to quantities, lot for lot, and so on. However, as discussed in later sections of this Desk Guide, using the EOQ method requires careful planning for every item in the inventory.

Figure 6 shows the independent demand pattern. Unlike the dependent demand schematic (Figure 5), demand is not constant; it fluctuates as material is needed. As a result, reordering of material follows the use of the material. It is not constant and does not have a discernible pattern. Section 3.3.3 discusses the types of replenishment methods available based on the material demand patterns.

Fig. 6 Independent Demand



3.3.3. Replenishment Methods

There are many methods available for replenishing inventory material. In this section, six of the most commonly used are discussed.

Dependent Demand	Independent Demand
Fixed Schedule	Two Bin System
Fixed Order	Reorder Point/EOQ
	Min/Max
	Fixed Period Quantity

3.3.3.1. Fixed Schedule

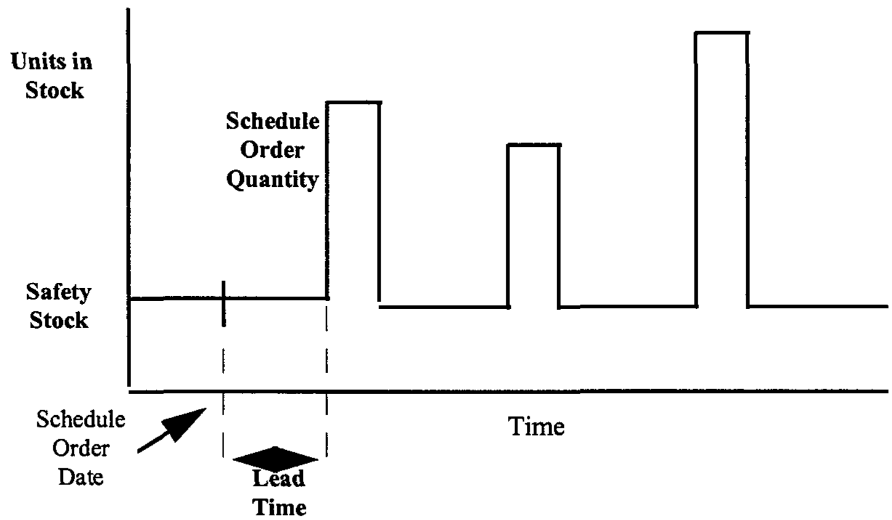
The fixed-schedule method of inventory replenishment is used when the time interval for ordering material is fixed (i.e., monthly, quarterly, etc.), but the quantity of the order is not fixed and may vary from one order to the next. This category includes materials for projects such as fleet-wide changeouts or scheduled maintenance activities and frequently used materials such as filters.

Conditions that should be met when determining whether the fixed-schedule method of replenishment is appropriate are as follows:

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

Figure 7 shows the sequence of events for ordering material on the basis of the fixed-schedule method. Following that is a sample fixed-schedule worksheet showing actual movement of inventory.

Fig. 7 Fixed Schedule



Fixed-Schedule Worksheet (Project XXX)

Part 1 -- 2-month total lead time
-- 7 on-hand
-- 10 on order

	(Months)				
	1	**2**	**3**	**4**	**5**
Gross Requirements	0	10	15	*5*	*5*
Quantity Available	7				
Schedule Receipts	0	10	0	0	0
Projected Available					
Net Requirements					
Planned Release					

	(Months)				
	1	**2**	**3**	**4**	**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**	-	-

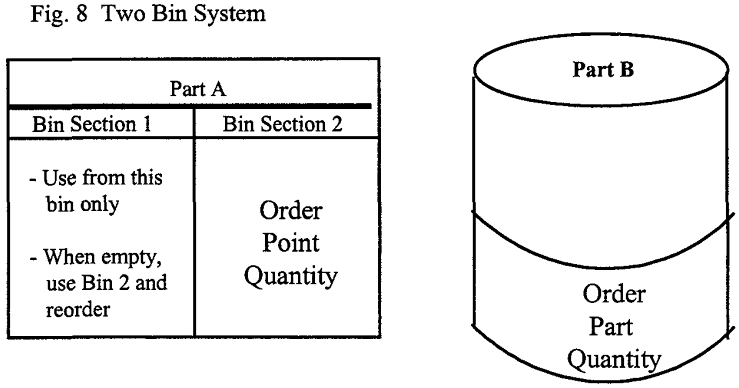
3.3.3.2. Fixed Order

The fixed-order method of material replenishment occurs where the size of the order is stable (fixed) but the timing of material delivery is based on actual demand. This method differs from the fixed-schedule method where the timing of the orders are fixed (i.e., monthly) but the quantities are dependent on actual demand. The fixed-order method of material replenishment is commonly used for seasonal demand items. This category includes seasonal requirements for such items as road salt or sand, or for air conditioning preparation. So as not to stock a full supply of this material all year round, it is necessary to program the systems to flag this material on a fixed-order basis. With this method, material won't keep showing up on reorder reports but would appear only at the time the order must be placed.

3.3.3.3. Two Bin System

The two bin method is often used for low-value frequently used material that can be planned for exact requirements or usage. Material frequently used with the two bin system includes nails, nuts, bolts, and other low-value, high-usage items. As shown in Figure 8, methods for replenishing such material are easy to implement and equally easy to track usage.

Fig. 8 Two Bin System



3.3.3.4. Reorder Point/EOQ

A reorder point/economic order quantity (ROP/EOQ) system requires that for every item stocked in inventory where the EOQ formula is used, a predetermination is made of the minimum and maximum levels required. Also assumed is that lead time is fairly constant. Figure 9 shows the flow of the inventory process using the ROP/EOQ method. As can be seen, all variables are constant, other than time. Assumptions for using the ROP/EOQ method are as follows:

- Item cost does not vary
- Order size does not vary
- Lead time is constant and known
- Storage costs are linear

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

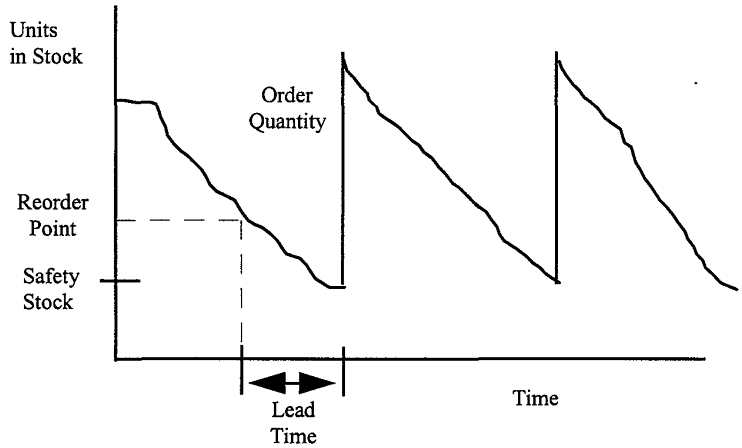
A typical reorder point calculation is shown below:

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

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

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

Fig. 9 Reorder Point/EOQ System

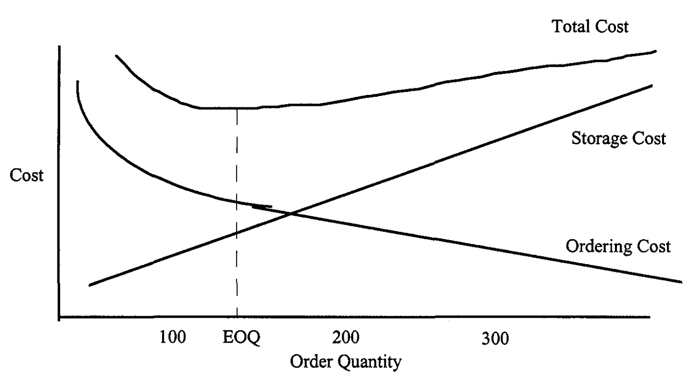


The goal of the EOQ is to minimize the total cost:

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

Figure 10 displays the EOQ formula and calculation:

Fig. 10 EOQ Formula



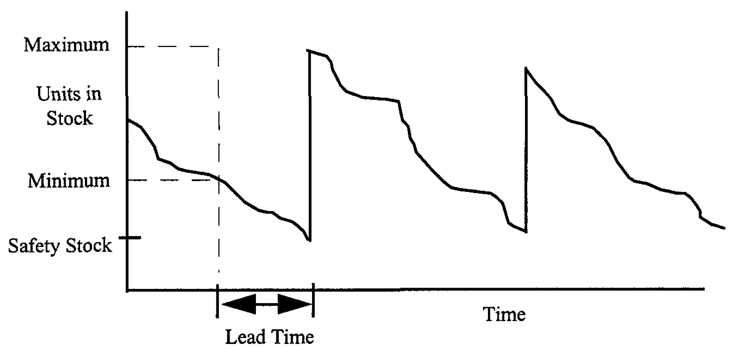
$$\text{EOQ} = \sqrt{\frac{\mathbf{2 \times Ordering\ Cost \times Annual\ Usage\ Units}}{\mathbf{Average\ Price \times Carrying\ Cost\ \%}}}$$

Because the requirements for using a ROP/EOQ system may be difficult to achieve (constant and known demand and lead time, instantaneous replenishment, and linear storage costs) a more appropriate method for determining material requirements with irregular usage patterns would be min/max. A discussion on min/max follows.

3.3.3.5. Min/Max System

The min/max system is used for items where material demand (or usage) is constantly changing. It is based on the maximum and minimum amounts of material that the user (not a system calculation) determines. In this type of system, maximum and minimum numbers of units to be stocked are determined plus the amount of safety stock required until the next order is filled. Whenever the inventory on hand reaches this 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 if necessary. The major difference between the min/max and EOQ systems is that the size of each order can be varied based on need. The EOQ system assumes a stable and independent demand. Figure 11 displays the min/max system.

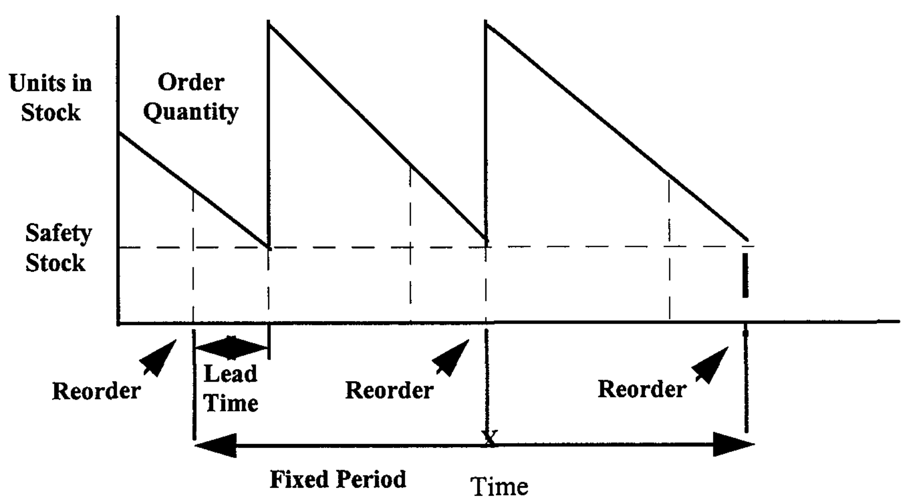
Fig. 11 Min/Max System



3.3.3.6. Fixed-Period Quantity

Fixed-period quantity is the fourth method used for computing what should be ordered to meet the independent demand. It is similar to the fixed-schedule method; however, while fixed schedule is used for dependent demand, or when the requirements are known in advance, fixed period is applied when material requirements can not be planned in advance (i.e., determined by uncontrolled factors) but once known the demand is stable. Types of material that could be applied to this type of replenishment method would be unplanned projects such as item changeouts, and so on. Figure 12 illustrates this method.

Fig. 12 Fixed-Period Quantity



The methods for forecasting and replenishing material discussed above are only a few of the methods available. Other computerized forecasting techniques include the weighted average and exponential smoothing. In the weighted average method, the computer system tracks the usage rate for a given period of time, say the previous quarter. Then applying a weighted average, set by the material planners, the system calculates the material demand for the next quarter. In exponential smoothing, based on monthly reordering, the items to be ordered are counted and the number of items on hand is entered into the computer. The number on hand are then subtracted from the previous month's inventory and by adding the number of orders received during the month, the usage rate is determined. Further, other methods for forecasting material requirements are regression analysis, Box Jenkins, and Shisken time series.

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

-- Historical data (when available) for each part number or unique item (usage on a per month basis for the past 3 to 5 years if possible)

-- A plan for controlling the material. By using a simple ABC analysis based on annual dollar usage (with A items being those with the highest annual dollar usage), energy can be concentrated on planning for and controlling the approximately 20% of the inventory items which account for approximately 80% of the dollars invested in the inventory.

-- A determination of lead times. Lead time is composed of 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 a need is recognized to order new items to the date that 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. The determination of lead times is perhaps the most crucial when it comes to forecasting material needs, and it is often the most difficult. Lead times can be determined for each single item or for like items (such as common hardware); however, lead times generally can not be applied to a vendor's entire stock of parts or materials. Lead times are affected by such variables as off-the-shelf versus made-to-order, scheduling of production runs, 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 established 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 regarding changes in parts usage due to changes in fleet configuration, the addition of new models, and so on.

One formula frequently used is as follows:

(monthly demand + safety stock) + orders not yet filled + (lead time x monthly demand) -(quantities on hand) - (on order quantities not yet received)

Results that can be achieved through good material forecasting include the following:

-- *Reduced annual maintenance costs:* people are no longer "running to the store" to buy parts and materials at premium costs

-- *Reduced equipment downtime:* the materials needed are on-hand and lead times are no longer a problem

-- *Better inventory management:* dangers of excess inventory on hand or running out of material when its needed are greatly reduced

-- *Improved morale:* maintenance staff are now satisfied that they will get their materials when they need them and planning staff have developed a team relationship with maintenance

3.4. Target Volumes and Stocking Points

3.4 1. Inventory Volumes

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, the scrap rate, the cost of material, lead time, or some combination of the above.

3.4.2. Inventory Stocking Points

Use the following guide in determining stocking points and where an item should be stored:

Guidelines

Characteristic of an Item	Central Storehouse	Satellite Site
Urgency of need	Can receive within 24 hours	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

4. STOREHOUSE OPERATIONS

4.1. Storehouse Network

Size and locations 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, the storehouse network is centralized. When storehouses are supplied. independently of one another, the network is decentralized. Generally, a centralized storehouse network is considered to be more efficient and cost-effective for several 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.

Storehouses should be located as close as possible to the location where the material will be required. For maintenance material, this is usually in or adjacent to maintenance facilities. If your inventory system includes administrative materials and supplies, then a storeroom should be located so that the inventory is easily available to the customers.

Storehouse layout is determined by the mix of materials stored, the size of the items, and any special storage requirements. Stores should be cost-efficient and provide for ease in changing configurations as the materials requirements change. Today's storerooms have access to many different types of shelving, racks, and filing systems.

The stores function is responsible for the following:

- Providing physical security and safekeeping of material
- Maintaining accurate inventory records
- Determining physical layout of storehouses including bin location assignments

- Monitoring physical movement and distribution of material throughout the organization
- Receiving and storing material
- Issuing stock material in response to a request from customers
- Conducting cycle counts or physical inventories of inventory material

4.2. 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 and to maintain accurate inventory records so that vehicles are not held out of service because of lack of parts, excess material can be reduced, project schedules can proceed on time, maintenance productivity is sustained, deliveries arrive on schedule, and over-ordering is kept at a minimum. In addition, maintenance of accurate inventory records will lead to better cost control. Secured and controlled access is also necessary to maintain orderly and effective housekeeping and to reduce or eliminate problems with material shrinkage.

4.3. Parts Storage and Release

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

Only designated personnel should be authorized to pick 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 also on a maintenance request or repair order. Recording the parts on the maintenance request or repair order will allow the tracking of the part to a piece of equipment or location. This will provide an audit trail and also assist maintenance management in tracking repair costs by vehicle.

5. PARTS MANAGEMENT

5.1. Catalog

The parts catalog is a record, often 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, specification number (if applicable), and minimum quantity on-hand. This information can be provided by using a computerized information management system or hard copy.

5.2. Excess/Obsolete Items

If the inventory contains a large amount of obsolete items, the inventory may be overvalued. Obsolescence is one of the components of inventory carrying cost. Too much excess inventory will drive up the cost of the inventory and capital that would otherwise be used more productively is unavailable. All excess and obsolete material should be eliminated from the inventory. While 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 conducting cycle counts or physical inventories, more space freed up for new more useful material, and a reduction in the valuation of the inventory. As usage is tracked, slow moving inventory should be highlighted. Obsolete or excess inventory can be identified in a number of ways such as establishing a policy on the number of years without an issue. Turnover, discussed in more detail later in this Desk Guide, is one measure that can be used to track the effect of excess inventory.

6. INVENTORY ACCOUNTING AND PHYSICAL CONTROL

6.1. Inventory Records and Accuracy

Accuracy of inventory records is necessary in order to

- Provide satisfactory customer service
- Determine replenishment of individual items
- Assure material availability to meet repair or project demand
- Analyze inventory levels and dispose of excess inventory

Issues associated with usage, charging, and expensing inventory parts, stock-outs, transfers, receipts, and backorders are discussed below.

6.2. Valuation

Below, four available methods for valuing inventory are presented:

1. **FIFO, or first-in/first out.** The oldest (or first received) material on hand for a given item is used to value that item. When using the FIFO method, later material purchased tends to be undervalued. This technique is primarily used for high-turnover items, typically in the manufacturing industry.

2. **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 earlier items purchased.

3. **Average cost.** The cost of all material taken into inventory is continually averaged so that the item cost is reflective of both the oldest and newest material. This method is used for operating material in both manufacturing and maintenance environments. One variation of average cost is *storeroom average cost.* When using this method, inventory costs are calculated for individual storehouses.

4. **Order specific cost.** Order specific costs are maintained on an item by item or 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.

6.3. 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 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 a medium value; and C items are those with the lowest annual dollar usage or the least value. Cycle counts are conducted periodically throughout the year to verify the accuracy of inventory records and value.

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

Implementing a cycle counting program will alleviate 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 with less impact on customer service.

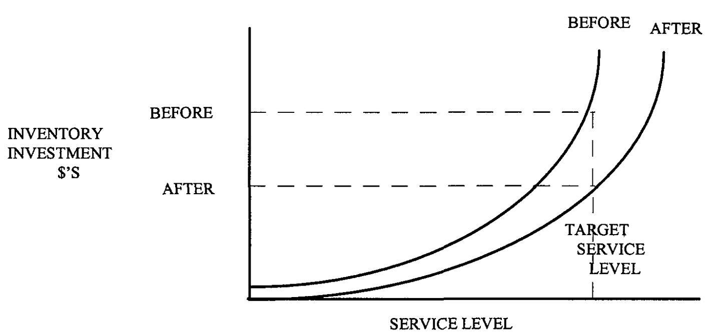
6.4. Physical Inventories

Physical inventories are used less frequently today than the more popular cycle counting method. 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 since 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 number of inventory locations. This in turn means that all transactions must be "held in suspense" until the count is completed and the records verified. Many times the result of the annual physical inventory requires a large financial adjustment at the end of the year because many items may be out of balance due to one reason or another.

7. EVALUATING THE INVENTORY MANAGEMENT FUNCTION

As discussed earlier, the objective of inventory management is to meet service level targets with the minimum inventory investment. Figure 13 illustrates this concept. As shown, with the target service level constant, a decrease in inventory investment can achieve the same level of service.

Fig. 13 Inventory Investment and Service Level



The following sections discuss available methods for measuring how well these objectives are met.

7.1. Performance Measures and Indicators

The total costs of inventory are shown below along with the components of these costs:

1. Preparation costs ➡ planning and ordering
2. Transportation costs ➡ receiving, distribution
3. Carrying costs ➡ capital, storage (handling, security, space, records), obsolescence, pilferage, deterioration
4. Stockout costs ➡ backorders (recordkeeping, emergency procedures, missed or late service runs)

7.1.1. Customer Service

Customer service can be defined as "providing material when the user needs it." The customer can be either (1) a user of material or (2) other storehouses. In order 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
- Backorders (stockouts)

Measures of customer service are (1) initial material delivery performance and (2) backorder or stockout resolution performance.

Initial Material Delivery Performance can be defined as follows:

A. Percentage of:

1. Requests 2. Line items requested 3. Total units requested	}	Filled on schedule
4. Periods 5. Operating days	}	Without a stockout

B. Number of:

- Stockouts* per period
- Idle work hours due to a stockout
- Vehicles out of service

Stockouts may be defined as zero items in inventory, no items available when requested, no items available when work starts, or number of open orders. Be consistent with definitions.

Backorder (Stockout) Resolution Performance can be defined as:

- Aging of backordered material requests
- Percentage of backordered material requests filled within specific time periods
- Number of days out of stock

Examples of measures for determining customer service levels are shown below.

Delivery Performance Measures	**% 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 = x stockouts per month
	% of Unfilled Orders Due to Lack of Material	Number orders requested / Number orders filled
	Example:	90 / 81 = 9% unfilled orders
	Percent of User Requested Items Filled from Inventory	Number orders filled / Number items requested
	Example:	72 / 78 = 92% item requests filled

	Average Time to Fill Backorders	Total no. days to fill all backorders / Total number backorders
	Example:	432 / 65 = 6.65 days
	Average Number Vehicles Held Out-Of-Service for Parts per Day	Total number vehicles held / Service days
	Example:	15 / 20 = 0.75 vehicles
	Percent Maintenance Hours Lost Waiting for Parts	Non-productive mechanic hours / Total available mechanic hours
	Example:	14 / 192 = 7% maintenance hours lost
Backorder (Stockout) Resolution	**Number of Days Out of Stock**	Date received - date of stockout
	Example:	June 20-July 7 = 13 days

71.2 Inventory Investment

Factors affecting inventory investment are as follows:

(1) Nature of inventory material

- Breakdown maintenance parts
- Project inventory
- Preventive maintenance parts

(2) Service level objectives

One method for measuring inventory investment is as *Inventory Value* (total inventory dollars). The formula for measuring inventory investment is

(Units On Hand) x (Average Price)

Total inventory dollars measures the total capital investment in inventory parts, materials, and supplies.

Inventory Turnover Rate (ITR) is a second measure of inventory investment. It can be measured as

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

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 measure of inventory investment is *Time Period Coverage* (months on hand). The formula for measuring months on hand is shown below.

$$\frac{\text{Total Inventory Dollars}}{\text{Monthly Usage Dollars}}$$

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

The following table presents examples of the measures of inventory investment shown above.

	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

7.2. Benchmarks

Benchmark values for inventory performance indicators are presented below. 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 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: the average value
- Median: the middle value (equal number of respondents above and below)
- Maximum: the highest value
- Minimum: the lowest value
- 20th percentile: the value greater than 20% of the responses
- 80th percentile: the value greater than 80% of the responses

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%	0.013%	0.047%	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%	0.005%	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%	0.01%	2%	13.8%
Rail % obsolete items	6.1%	5%	20%	1%	1.12%	10%
Bus days to fill backorder	16.4	10	90	1	3	30
Rail days to fill backorder	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 SUMMARY

As stated throughout this Desk Guide, materials managers are continually challenged by the two conflicting objectives of inventory management--to provide maximum parts availability while keeping inventory investment low. The objective of this guidebook has been to provide a framework for transit managers and staff to use to better understand, evaluate, and manage inventory. Because of the wide variance in the size of transit agencies and the services provided, the information presented should be used as a framework for improving inventory management and customer service. The techniques and methods described should be adapted based on the size of the operation, types of material stored in inventory, and the management tools available.

The inventory management indicators presented in the final section 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 or between transit organizations.

When comparing benchmark values among public transit agencies, the characteristics of the public transit agency or the agency's fleet may have an impact on inventory performance. For example, the population of the agency's service area, the number of annual passenger miles, the percent of foreign manufactured vehicles, or the average age of the fleet may have identifiable effects on inventory performance indicators. These effects should be taken into account when using benchmarks.