Chapter 20
Stock Control

Abstract The aim of this chapter is to describe the various aspects of inventory management required for asset management. This starts from the initial purchase of spare parts and consumables, and continues with through-life support. Inventory control methods are presented for routine demands and for fast and slow moving spares and insurance spares. *Outcomes* After reading this chapter, you will be aware of the main issues that confront asset managers in regard to spare parts and consumables inventory. You will know everything that is worth knowing about spare parts inventory management, but this will not mean that you can solve all the problems.

20.1 Introduction

The term inventory is applied to stocks of items such as finished goods, work-in-process materials, consumables, and spare parts held by an organization in order to carry out its business functions. The management of inventory extends to cover items which are on-order and are known as dues in, and items which are required by users but not yet available from the store, which are known as dues out, as well as to those items which are physically in stock at any given moment. In the asset management area, the items involved are typically:

- Consumables such as fuel, oil, lubricants, and chemicals.
- Spare parts.
- Rotables, which are items that are changed out, then repaired, and returned to store; this may include complete equipments.
- Insurance spares, that is items which we may never need but which we prefer not to risk being without.

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20.2 Aims of Inventory Management

The primary aim of inventory management in the field of spares and consumables is to enable the meeting of requirements for equipment availability at minimum overall cost. This will involve:

- Keeping service to the users at a reasonably high level
- Keeping inventory investment reasonably low
- Cost-effective purchasing.

A balance must be struck between these conflicting factors.

More basic aims of inventory management are to ensure that:

- Stock identity, quantity, and location are known;
- Stock is secure;
- Items are available and accessible when required;
- Purchase orders are placed promptly;
- Goods are received and checked efficiently and effectively.

20.3 Initial Spares Purchase

When a new equipment is acquired, we normally purchase an initial quantity of spare parts. This may be based on the manufacturer's recommended spares list, or on input from experienced maintainers. The acquisition budget should include funding for the initial spares purchase. An amount in the range of 5–10 % of the main equipment budget is typically allocated. The initial purchase or “scaling” is based on a planning horizon such as 3 years. Major spares, such as replacement engines and gearboxes, which may go out of production by the time they are needed, should also be included. It is hard to get it right on forecasting demand and some over and under supply must be expected.

20.4 Cataloguing

Parts will be identified by means of a part number within the organization’s inventory management system. It is therefore necessary to catalog the items which the organization will hold. An agreed system of codification will need to be adopted. The equipment manufacturer will normally provide a parts list for spare parts which will include parts explosion diagrams and part numbers. However, if these are to be incorporated into a company inventory system, it will be necessary to catalog the parts under the company’s part numbering system. The computer record will normally also contain the identification of the manufacturer and the

manufacturer's part number. Resources will be needed for the cataloguing activity and for maintaining the computerized inventory management system.

20.5 Inventory Management Basics

A flowchart of inventory transactions is shown in Fig. 20.1. Inventory management is invariably based on a computer system and will be part of an Asset Management Information or Computerized Maintenance Management System. Knowing the current status of any given item requires a comprehensive, online transaction processing, inventory management information system. Up-to-date and accurate information is more valuable than any theory.

The following points are counsels of perfection for inventory management.

- Have one person responsible for the inventory management system.
- Provide an adequate computer system and personnel for system support.
- Maintain security, particularly in regard to attractive items.
- Have an effective coding and cataloguing system with unique part numbers.
- Maintain stores accuracy in regard to quantities, locations, and item descriptions.
- Establish bills of materials and where-used data.
- Ensure work orders contain all spares and materials required for the job.
- Establish and use strict procedures for receival and issue of stores.
- Have a system which allows 24/7 access to spares for urgent maintenance jobs.
- Establish and use strict procedures for the timely reordering of stock.
- Maintain the computer system in regard to updating supplier and stock records. Ensure staffing is adequate to sustain this.
- Carry out regular stock-takes, usually on a cyclic basis.
- Make stores records visible to users. Extend this company-wide, and have a transfer system between locations.
- Establish data for average demand and for specific project demands.
- Establish item criticality. Have a system for keeping this information up-to-date.
- Set reorder parameters.
- Eliminate dead stock.
- For fast moving items, establish Just In Time delivery procedures.

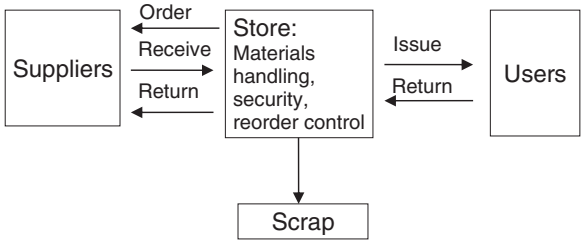

Fig. 20.1 Inventory system

20.5.1 Stock Keeping Units or SKUs

An SKU is a point at which a given item is stocked. A company may have 10,000 different types of item in inventory, but some of them may be held in more than one place. So if the main store is in Melbourne and it holds all 10,000 types of item and there is a subsidiary store in Upper Wup Wup which only holds a subset, say 4,000 types of item, then the company has 14,000 SKUs. The number of SKUs gives a measure of the total size of the inventory management side of the business.

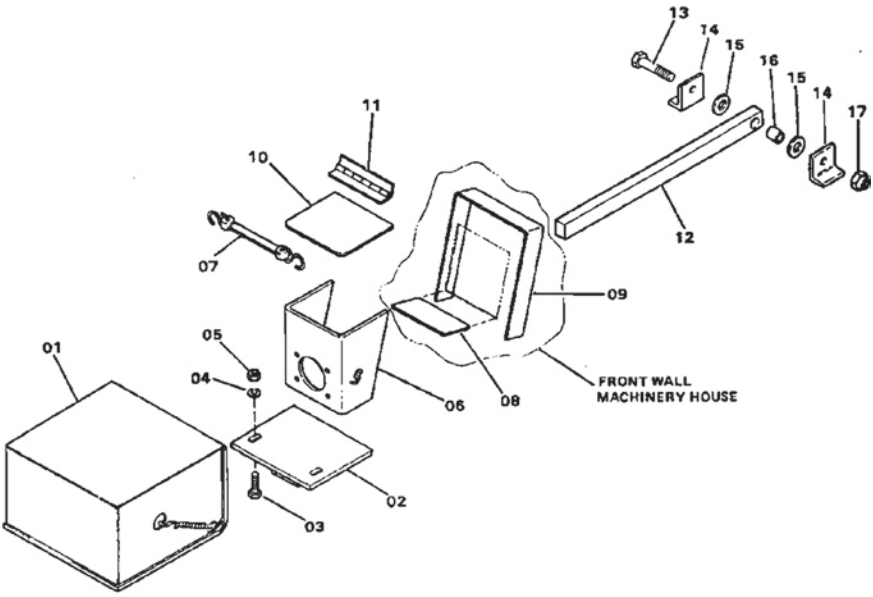

Fig. 20.2 A parts explosion diagram

Ref	Part No.	Description	Qty.
0	100J6493F4	Installation, Boom Limit Switch	1
1	979J23F1	Switch, boom limit	1
2	16N3651D1	Bracket, support	1
3	20Q260D329	Screw, Hex Head Cap ½-13UNC X 1-3/4in	2
4	3616V011	Washer, lock, 1/2in	2
5	20Q270D32	Nut, ½-13UNC	2
6	16N3649D1	Bracket, mounting	1

Fig. 20.3 Extract from a parts catalog

20.5.2 Spare Parts Catalog

Basic elements of spare parts data for engineering equipment are the spare parts explosion diagram and spare parts catalog listing, examples of which are shown in Figs. 20.2 and 20.3.

20.6 Procedure When an Item Is Needed

The basic steps involved when an item is needed from inventory are as follows:

a. An item is needed;
b. Get the part number. Refer to the spare parts explosion diagram and the catalog;
c. Is the item in stock?
d. If so, where is it? Pick the item from the location;
e. Follow the issue procedure, documenting the issue;
f. Do more items need to be ordered? This will be the case if there is insufficient in stock, or if the withdrawal takes the stock level below the reorder point;
g. If so, how many should be ordered? The order quantity may have been set in the inventory system, but enough should be ordered to cover foreseen requirements;
h. Follow the reorder procedure. Get the supplier details. Initiate a purchase order;
i. If the supplier is not already in the system an entry must be created.

20.7 Stock Status and Control Terminology

To find out if the item is in stock we will refer to a computer screen similar to that shown in Fig. 20.4.

Date: 18 Sept 97 **Time**: 14:47:05 **Location**: BIN 46

Parent Item: P & H Shovel **Manufacturer**: Hamischfeger

Part Number: 16W316D1 **Description**: BRACKET, Mounting

Manufacturers Ref: BLS06 **Unit**: EACH **Lead Time Days**: 14

Reorder Level: 1 **Reorder Qty**: 2 **Unit Cost**: $153.07

YTD Used: 1 **Last Activity Date**: 30 Aug 97

Current Stock Level: 0 **Net Level**: 0

Dues In			Dues Out		
Date	**PO No.**	**Qty**	**Date**	**WO No.**	**Qty**
3 Sept 97	PO4371	2	12 Sept 97	WO123	1
			18 Sep 97	WO234	1

Fig. 20.4 Inventory status report screen

Part No: A43WS582-Grease. Unit: kg; Date: 05Jul Time: 10:15
Lead Time Days: 28 Supply Multiple: 50 Supplier ID: 3427

Row	Date	Note	Due In	Due Out	Net Level
1	06JUL	Stock			13
2	06JUL	PO-123	50		63
3	10JUL	WO-456		25	38
4	19JUL	Dragline Servicing		50	-12 **
5	28JUL	PO-145	100		88
6	01AUG	Ballmill Servicing		25	63
7	10AUG	Shovel Servicing		35	28
8	17AUG	WO-475		45	-17 *

** = Shortage within one lead time. * = Shortage within two lead times.

Fig. 20.5 Materials requirements planning report

In Fig. 20.4 the following terms are used, and play the roles indicated as follows:

Current Stock Level The number of items in stock.
Dues In Items ordered from a supplier but not yet delivered.
Dues Out Items demanded by a user, but not yet issued.

Dues out can include items not yet ordered from a supplier, items ordered from a supplier but not yet received, and items received but not yet issued. These items may be referred to as "committed," as they are already known to be demanded by specific users.

Lead Time Days The time between ordering and delivery.
Net Level Current Stock Level + Dues In − Dues Out.

The net level is the stock level that we shall have if we add the dues in to our existing stock and then subtract the dues out. It is the balance of our stock situation allowing for existing planned stock movements. If the result is below the *reorder level*, an order for the *reorder quantity* should be placed.

Another term which is used is:

Backorder An item is on *backorder* or *backlogged* if it is not in stock, has already been ordered from a supplier, but the order has not yet been received.

20.7.1 Multiple Locations and Status Settings

It is easy to grasp a situation where items are either in stock or not. However, variations on the theme arise in practice. Computer systems need to allow for many possibilities but this can make the situation less clear that you might wish. A given

stock item may be held in a number of locations. Also the status of the item can have variations, such as:

Received but not cleared into stock,
In transit,
In stock but reserved for a project,
In stock but reserved for emergency,
Assigned for disposal.

Transactions between these and other status categories at all the various locations can lead you to use a little black book in which you keep track of the things you really want to know about. This is not defensible in theory.

20.8 Dependent Demand

Dependent demand is demand which can be estimated or planned, by time and quantity, from a production plan or a scheduled maintenance plan. Examples are:

- The consumption of fuel, for a known vehicle fleet operating to an established production or delivery schedule.
- Consumption of chemicals or other consumables used in a number of routine or planned applications.
- Spares such as spark plugs or brake pads used in an established scheduled maintenance plan.
- Spares which are ordered for a known repair, or for a shutdown involving planned replacement of components.

If dependent demand is quite regular it can be managed by routinely ordering quantities sufficient to cover the demand. Occasional variations from average will be dealt with by varying the order and by holding a safety stock.

20.8.1 Kanban System

The initiation of the reorder process may best be handled by a Kanban system. In a Kanban system the reduction in stock below the reorder level is indicated by a physical card which is released when the critical stock level is reached. This is theoretically the same as an electronic signal, but the physical card can be easily recognized. The card will indicate the quantity to be reordered.

20.8.2 Materials Requirement Planning (MRP) Report

If demand is dependent mainly on known but irregular activities, we use a Materials Requirements Planning (MRP) analysis and report of the type shown in Fig. 20.5. The item referred to in that example is a type of grease, purchased

in multiples of 50 kg, which is used in servicing major machines such as mining shovels, draglines and ball mills.

In Fig. 20.5 the rows correspond to planned events in date order. The first row shows the opening stock which is 13 kg and this quantity appears in the Net Level column. Existing purchase orders provide data for the Due In column. Row 2 shows that we currently have 50 kg Due In under Purchase Order PO-123 on 6 July. The Net Level column shows the projected stock after each planned transaction. In row 2 the Net Level is 63, as the 50 kg from the PO-123 are added to the stock of 13. The data for the Due Out column is created from the current utilization plan. The next planned event is a Due Out of 25 kg required on 10 July by Work Order WO-456, which will reduce the Net Level to 38 kg.

The report continues projecting forward the Dues In and Dues Out, running as far ahead as we choose to plan, usually at least two delivery lead times ahead. In this case, the lead time is 28 days so we will plan for 2 months ahead. The Net Level column will eventually show a shortage, represented by a negative net level. This is an indication that we need to take action so that the shortage is prevented. If the shortage first occurs more than one lead time ahead, we cover the shortage by placing an order. If a shortage occurs within the normal lead time, we need to take special action. This may be placing a rush order, delaying the lowest priority use, or providing a partial quantity to one or more demands.

Every change in the supply or demand situation requires a revision of the Materials Requirements Planning Report. However, in practice it is usually sufficient to generate a new report at a convenient regular interval such as daily for critical items or weekly for noncritical or slow moving items.

20.9 Independent Demand Items

Independent demand items are items for which demands occur on a variable basis, such as spare parts required for unpredictable breakdown repairs.

20.9.1 Fast Moving Items

For fast moving independent demand items, a typical cycle of stock level from order to reorder is shown graphically in Fig. 20.6.

The stock level is shown vertically and time is shown horizontally. The stock level following an earlier delivery starts at some initial value as shown on the left-hand axis, and then falls irregularly over time. The current net stock position is monitored, and when it falls below the *reorder level*, an order for a *reorder quantity* is placed. There is then a *lead time* after which the order is delivered. The stock then increases by the reorder quantity and a similar cycle of events is repeated. Control of the stock is effected by setting appropriate values for the reorder revel and reorder quantity.

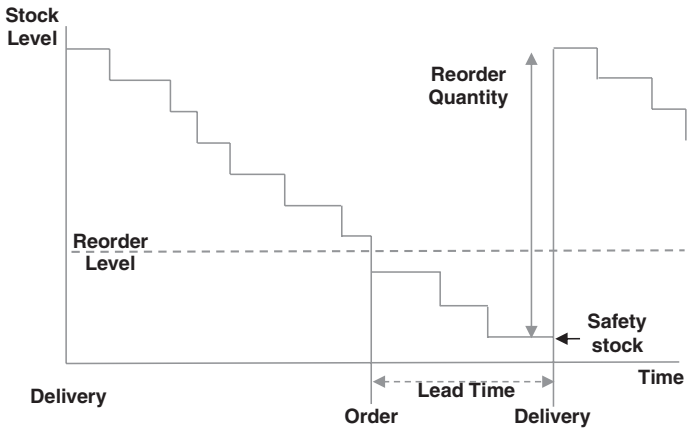

Fig. 20.6 Fast moving items—reorder cycle

20.9.2 Reorder Level

The reorder level is a stock level such that, when the net stock falls below it, an order should be placed. The *reorder level* is represented by the horizontal dotted line in Fig. 20.6. A guideline value for the reorder level is twice the average demand in the lead time.

20.9.3 Lead Time

Lead time is the time taken from when the net level falls below the reorder level until the item becomes available for issue. The estimate of the lead time should include:

- Time that it takes us to identify that stock has fallen below the reorder level
- Time taken to place the order
- Time from the supplier receiving the order to delivery
- Time taken from delivery until the item is available to a user, e.g., checked in and placed on the shelf.

During the lead time stock will continue to be used. The average amount of stock used in the lead time is known as the average lead time demand, or simply as the lead time demand. The reorder level should be set to a level which will usually cover the lead time demand, so that no actual stockout occurs. However, if the reorder level is high, it will mean that excessive stock is often being carried. A guideline value for the reorder level is twice the average demand in the lead time.

20.9.4 Reorder Quantity

The reorder quantity is the quantity to be ordered. This is typically a convenient handling quantity of 1–3 months demand, with possible consideration of quantity discounts. However, even with discounts it is rarely worth ordering more than 1 year's supply.

20.9.5 MIN and MAX

The stock control process may also be presented in terms of minimum (MIN) and maximum (MAX) values. MIN is the same as the reorder level, so that an order is placed if the net level is below MIN. MAX is a maximum stock level. MAX can be regarded as similar to the reorder quantity, but it also gives the stock controller the option of ordering a varied amount if the circumstances call for it, so that we order enough to bring the stock up to MAX.

A great deal of statistical analysis has gathered in the literature about stock control, but as a rough guide, the reorder level or MIN should be twice the demand in the resupply lead time. The reason for this is that this policy will cover the possibility that something goes wrong in the reorder process. The fault will be identified after one lead time, leaving a second lead time for the mix up to be rectified.

The reorder quantity or MAX should be a convenient ordering and delivery quantity, sufficient to cover demand for a readily foreseeable period ahead, such as 1–3 months.

20.10 Target Level

A variation on the MIN and MAX method of stock control is the Target Level method. In a target level policy, if at the time of ordering, the net level is below a set target level, then sufficient is ordered to bring it up to the target level. This approach is convenient if routine deliveries occur with the quantity to be ordered being flexible from delivery to delivery. Regular milk deliveries and weekly grocery purchasing are examples. In this method, the MIN level is not used but the MAX level acts as a target. If the net level is below MAX, then sufficient is ordered to bring it up to MAX. With all methods, adjustments may need to be made for exceptional demands or shortages.

20.11 Forecasting

Scientific reorder control for independent demand items depends on estimates of the average demand per month and the average resupply lead time. These parameters can vary through time and a forecasting system, or more truthfully, a demand

tracking system should be used to track variations in the demand. The simplest systems are based on calculating a *moving average* of demands. The average will rise or fall as demand changes and the reorder level and reorder quantities should be linked so that they follow the changes.

For spare parts, the *exponentially weighted moving average*, or *exponential smoothing* method is recommended. It has the advantage that, in the case of *slow movers*, it will vary gradually, whereas a 12 months moving average, for example, would fall to zero after a year with no demand.

Besides variations in the level of demands, there can be seasonal variations and trends. Changes in trend are difficult to deal with automatically and may require human intervention to correct the forecasts. Another difficulty is outliers, that is, exceptional circumstances which may rarely if ever repeat. A classic in the Australian bush is the demand for fencing wire, for which a bush fire running through a region can cause a once-in-a-lifetime outlier in demand.

Lead time variations are more likely to be caused by administrative changes; for example, changes in supplier, in the delivery system, or the communication system. Shorter lead times are beneficial in providing a more responsive system. Long lead times due to shipment by sea need a more strict attention for lead time estimation.

20.12 Reorder Risks

Risks to the smooth running of the reorder process include:

a. Failure to identify when the net stock level has fallen below the reorder level or MIN
b. Lumpy demand causes a shortage
c. Failure to place the required order
d. Wrong item ordered
e. Order not received by supplier
f. Order not acted on by supplier
g. Wrong item sent
h. Loss in transit
i. Item wrongly identified
j. Item faulty at receival quality check
k. Item misplaced or lost on site
l. Item faulty when brought into use.

These risks are often more significant in practice than any fine tuning which may be achieved by statistical approaches to reorder level setting.

20.13 Inventory Faults

Some common faults in the management of inventory are as follows.

- Items not assigned a formal location but kept in casual or inconsistent locations;
- Item location not recorded;
- Item kept in multiple locations for no valid reason;
- Item not in computer inventory system;
- Item not in purchasing system;
- Description of items is missing or incomplete;
- Varied descriptions or codings for identical item;
- Part number, manufacturer, or manufacturer part number not specified;
- Hazardous conditions not specified;
- Stock control parameters not specified (Max and Min or reorder level and reorder quantity);
- Lead time for resupply not specified;
- Shelf life not specified;
- Default supplier not specified;
- Last or current purchase details not readily accessible;
- Freight company not specified;
- Stocktake not performed, incomplete, or not recorded; and
- Items held informally by various people.

20.14 Safety Stock

The expected level of stock remaining at the end of the lead time is known as safety stock. If the reorder level is twice the average lead time demand, as recommended, the safety stock is equal to the average lead time demand. When the lead time elapses, we expect the item to be delivered. If it is not, then we should check why. If the order is not on track, then the safety stock will provide cover for an additional lead time in which to get supply.

20.15 Item Criticality

Critical items are items that are particularly essential to the operation of the organization. Reviewing item criticality requires a knowledge of which machines and processes are most critical to the business. Critical items will normally be:

- Consumables that are essential for mainstream operations,
- Spares that are essential to maintain mainstream plant.

Criticality can be dealt with by increasing the reorder level (or MIN) where criticality is identified. As a guideline, increase the reorder level by 25 % and round

up to the next integer value. So a noncritical reorder level of 5 will become a critical item reorder level of 7. For critical dependent demand items, use the Materials Requirements Planning method shown in Fig. 20.5.

20.16 Summary of Reorder Rules Fast Moving

Reorder Level or MIN = 2 * average lead time demand, rounded up.
Reorder Quantity or MAX = 1–3 months demand, rounded to a convenient purchase quantity.

For critical items increase quantities by 25 %. Do not order more than will last for the shelf life.

20.16.1 Stock Control Example

An item has an average demand of 4 per month and a lead time of 2 weeks. What MAX and MIN values should be set?
Solution: Take the 2-week lead time as corresponding to half a month. The average demand in the lead time is 2.
We set MIN = 2 * average demand in lead time = 2 * 2 = 4
We choose to set MAX to be 3 months demand, MAX = 12.
Thus the control parameters are:
MIN = 4
MAX = 12.

20.17 Current Action

Stock levels must be reviewed, ideally at every issue, or on a frequent regular basis, e.g., daily.

At any time we may have:

- Stock on hand
- Dues In
- Dues Out
- Special Demands.

We should place an order if:

$$(\text{Stock} + \text{Dues In}) - (\text{Dues Out} + \text{Special Demand}) < \text{MIN} \tag{20.1}$$

The actual reorder quantity should be enough to take the net level, allowing for dues in and out and for any special demands, up to the MAX level.

Thus we have:

Net Level = Stock + Dues In − (Dues Out + Special Demand)
If Net Level < Reorder level then:
Actual Reorder Quantity = Max − Net Level
Round to allow for a Supply Multiple.

20.18 Complications

Several additional factors make stock control complicated and make fully automated control difficult. These include:

- *Supply multiple* Supply may be in quantity multiples which are convenient for packaging or transportation. A choice between available supply quantities will have to be made. For example, oil in 20 L cans or 200 L drums.
- *Price breaks* Price breaks occur depending on order quantities. The cost of oil per liter will be lower in 200 L drums than in 20 L cans. A decision to increase the reorder quantity to take advantage of a price break may be needed.
- *Issue multiple* Items are issued in multiple quantities, for example spark plugs. The multiple may be different for different applications, e.g., four- or six-cylinder engine.
- *Issue quantity is variable* The issue quantity varies from job to job, for example when an item is stripped down in some cases new seals may be used but in other cases, the existing seals may be left in place or reused or partly so.
- *Reserved stock* Items required for a critical machines, specific repairs, specific projects, or for a shutdown, may need to be held in reserve; otherwise, when the breakdown or shutdown occurs, the items will no longer be available and a major delay in can occur.
- *Kits* Some items form part of kits of components which are issued in a set to carry out certain repairs. When a kit is issued, a new kit should be prepared, and this will draw stock from the item store. Kits may sometimes be returned partly used, in which case the kit should be replenished. Kits may be raided for components in an emergency (oh no!).
- *Shelf life* The time for which an item can be stored before it deteriorates. This may be an issue. Do not order so much that the shelf life is exceeded. To avoid items lingering in the store, arrange for *first-in-first-out*, or *FIFO*, use of items.

20.18.1 Consignment

Stock on consignment is stock that suppliers provide into store, which is only invoiced as it is used. This can have advantages for the user who is not committed to unused stock. It can also suit a supplier who gets a guaranteed customer and perhaps also gets free storage.

20.18.2 Cannibalization

This term refers to a situation where we have two items of equipment which require different spares, and the spares are unavailable. We can take spare parts from one item in order to get the other one working. This is not an ideal situation but it may be the only practical resolution to return a needed item to production in a hurry.

20.18.3 Returned Stores

Returned stores are generally a curse but may sometimes be a blessing. The condition of returned stores may be hard to assess, and using them may give rise to safety problems. In the case of technical items, expertise is needed to identify and assess them and it is often not practical or economic to provide this. On the other hand, a scrap yard of returned stores or scrapped items may provide the only source of spares for old equipment. Where else will you find an authentic gearstick knob for your 1935 Chevvy?

20.18.4 Storekeeper Personnel

Employ ex-tradesmen in the stores. They understand the equipment, are sympathetic to the needs of operations and maintenance, and have the interests of the industry at heart. Young blokes off the street will know nothing—initially.

20.18.5 Overstocking

Stores people tend to be criticized more for shortages than for overstocking, so the tendency is to overstock.

20.19 Repair Pools and Rotables

A repair pool is a number of additional machines, assemblies, or components which are provided on a standby basis. When a failure occurs, an item from the repair pool is quickly brought into service. The failed item is then repaired and returned to the repair pool. Repair pools can significantly increase system availability at moderate cost. The items are referred to as *rotables*. Figure 20.7 illustrates the process.

It is important to initiate the repair cycle promptly. Sometimes the rotable is left languishing in a corner, with no replenishment action taken until a crisis occurs.

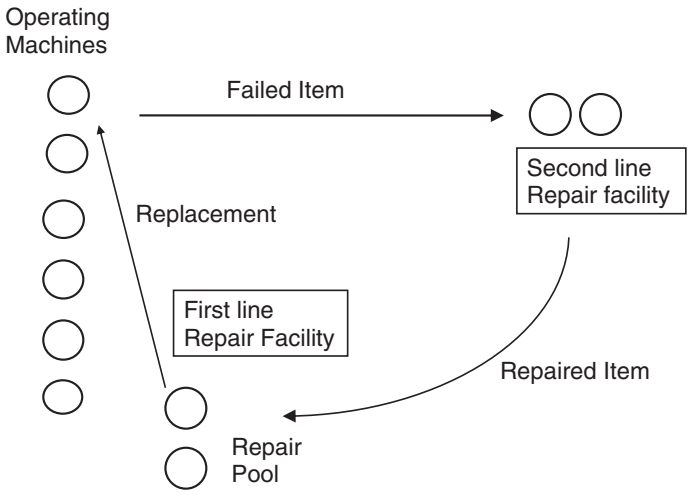

Fig. 20.7 Repair pool and rotables

In some cases, only the owner's own assemblies (identified by serial number) are returned to the owner's pool. A repair facility which deals with many customers (e.g., as an agent for a major OEM) may supply rotables which are not necessarily those which the owner has sent for repair, so that the failed item is really a financial trade-in. In this case, the mean time to replenish the repair pool may be less than the time to turn around a specific rotable. A judgement needs to be made regarding the appropriate lead time to use in estimating the size of the repair pool. As a guideline, the size of the repair pool should be twice the number of failures expected in the turnaround lead time. For critical items, one or two extras may be carried.

20.19.1 Repair Parts

Repair parts are items which are sent for repair to a higher echelon, but no repair pool is kept. The item is out of service while the repair is being carried out. In-between situations can arise if the repair part is replaced from stock or by cannibalization, but normally the user awaits the return of the repair part.

20.20 Slow Moving Items

A slow moving item is an item where the mean time between demands is much longer than the lead time. As a guideline, if the mean time between demands is more than ten times, the average lead time then the item is slow moving. Thus an item with an average demand of 1 per year and a lead time of 1 month is slow

moving. The *mean lead time demand* is the average demand in the average lead time. An item is slow moving if:

$$\text{Mean Lead Time Demand} < 0.1$$

For slow moving items, the probability of multiple demands in the lead time is very small. On the basis of the guideline just given, it is less than 0.01, assuming that demands are independent. Classify slow moving items into the following categories:

- "*Stock Zero*" items. Do not hold stock. In this case, you have to wait for delivery every time. This is also described as Order Only On Demand (OOOD).
- "*Stock One*" items. This is the default. Usually have 1 in stock. Order when stock reaches zero (MIN = 1).
- "*Stock Two*" items. Items for which extra safety stock will be held. Usually have two in stock. Order when stock reaches 1 (MIN = 2).

The choice of category for any given item is based on the following factors:

Demand Rate Low values reduce the holding. A mean lead time demand of less than 0.01 will usually result in a "Stock Zero" decision, that is, orders are only placed when a demand for an item eventuates. But consideration should be given to holding the item as an insurance spare, in which case we will have a "Stock One" policy.
Item Cost A high cost reduces the holding; for example, a high cost may result in a stock-two item being reduced to the stock one category.
Shortage Cost/Criticality Higher values of shortage cost or high criticality will increase the holding. This may push an item from the "stock zero" to the "stock one" category, for example.
Lead Time A long lead time increases the holding.
Safety and Environment Potential problems under these headings increase the holding.

The decision as to whether to hold stock of a slow mover, and if so, whether to hold one or two items can be assisted by considering the guidelines summarized in Fig. 20.8. Consider each factor in turn and tick one of the columns in regard to that factor. If none of the factors is compelling in terms of holding stock, then we would take the "No stock" option. Otherwise, the placing of the ticks might indicate that we should hold a stock of one or two. If it is really important to avoid a shortage and none of the other factors override this, then we may stock two.

Factor	No stock	Stock 1	Stock 2
Demand Rate			
Item Cost			
Shortage Cost/Criticality			
Lead Time			
Safety/Enviro			

Fig. 20.8 Guidelines for policy analysis for slow movers

20.20.1 Example

A consultant uses a printer which requires ink cartridges. The demand rate and lead time are low and the item cost and safety are not significant. However, the shortage cost or criticality, in terms of a cartridge running out at an inconvenient time is assessed as significant, so the decision is to Stock 1 cartridge (of each color).

20.21 Insurance Spares

An "insurance spare" is one where the probability that it will be needed is low, but the consequence of not having it is high, so on balance we decide to hold it. The item need not be high cost. In fact, low cost is an argument in favor of holding a spare.

For high cost and high shortage-cost items, have a contingency plan. This may involve:

- holding a spare equipment, this is an insurance spare.
- sharing this with others.
- arranging air freight as a contingency plan for an emergency.
- making a contingency agreement with the supplier.
- having a contingency plan which provides an adequate short-term solution, if feasible.
- setting up inventory and supplier file entries so that the purchasing process can proceed promptly when the part is needed.

20.22 Summary of Policy Types

For a given item, we need to decide what type of reorder policy should be used such as:

- *Independent demand* Reorder Level and Reorder Quantity (= Min and Max);
- *Dependent demand* Material Requirements Planning (MRP);
- *Routine restocking* Just In Time (JIT)/Kanbans; and
- *Slow moving* Zero, One, and Two stock holding policies.

20.23 Performance Indicators

20.23.1 Service Level

The *service level* is the proportion of items supplied at the time required. The service level is a performance indicator. However, the service level only measures

performance from the consumer's point of view and if it is the only performance indicator used, it will encourage overstocking.

20.23.2 Days Supply

Consideration of the number of days supply of items can help to highlight stocks which are excessive and ones which are in short supply:

$$\text{Days Supply} = \text{Net Stock} * 365/\text{Annual Demand}$$

Figure 20.9 shows an example of a days–supply report.

Note that Net Stock = Current stock level + Dues In − Dues Out.

Days Supply > 730 is more than 2 years supply, which normally indicates *dead stock* or possibly an insurance spare;
Days Supply > 365 is excessive stock or slow moving;
Days Supply < 365 and > 0 is normal;
Days Supply $\leq$ 0 is out of stock.

20.23.3 Dead Stock

Dead stock is items for which no future demand is expected. It is likely to be for items which are no longer used. Correct gross anomalies by transferring, writing off, and disposing of stock which is of no further use at a given location. But be careful not to overreact. Some items may be insurance spares or may only be required at long intervals.

Part No - Description	Net Stock Level	Av. Monthly demand	Days Supply
158904 - Bearing	356	0	9999
235611 - Flange	75	2.3	978
SR-24 - Hose	3900	25	156
7034452 – Seal	2	6	10
56902 – Desiccant	23	150	4.6
78/45WY6002 - Pipe	0	5	0
AD670013 – Valve	-3	2	-45

Fig. 20.9 Days–supply report

20.23.4 Stock Turns Per Year

Another indicator of the performance of the inventory system for any given stock item is *stock turns per year*. This is the number of items issued in the year divided by the number held in stock—typically at stock take time.

$$\text{Stock Turns Per Year} = \text{Annual Demand}/\text{Stock Level}.$$

For example, if the annual demand is 40 and the stock level is 10 then the Stock Turns per year is 40/10 = 4. This analysis can be useful in identifying items with high or low inventory movement.

20.23.5 Value Turns

Another performance measure is *value turns*. This is the annual demand value divided by the stock value at stocktake, taken over a range of stocks. For an individual item this is the same as stock turns. A low level indicates a low turnover rate of stock, which is inefficient.

Taking the Sum over a given range of inventory items:

Stock Cost = Sum (Stock Level * Item Cost)
Annual Demand Value = Sum (Annual Demand * Item Cost)
Value Turns Per Year = Annual Demand Value/Stock Cost

The value turns can be calculated for the entire stock or for sections of it. A useful assessment can be made by calculating the value turns for items in various ranges of days supply. Insurance spares, however, are a special case and should be kept out of the value turns calculation.

The cost-benefit of the current inventory can by examined by analyzing the cost of the stock and the value of the demand for that stock. Items with high stock cost but low demand value per year are poorly performing. These items should be eliminated unless they are being retained deliberately as *insurance stock* against assessed risks.

The example in Fig. 20.10 is based on a vehicle importer who had substantial amounts of dead stock, due to model changes. The dead stock items are those with 365+ days supply. These items also have very low value turns. Similar results occurred in an oil refinery with spares for obsolete plant.

20.23.6 ABC Analysis

Sort the items by Annual Demand Value (or "turnover").

$$\text{Annual Demand Value} = \text{Sum}(\text{Annual Demand} \times \text{Item Value})$$

Days Supply Range	Stock Cost	Annual Demand Value	Value Turns / Year
0 - 90	$257,498	$3,012,543	11.7
91 - 365	$1,752,107	$921,191	0.53
365+	$3,951,228	$142,201	0.04

Fig. 20.10 Inventory value turns

Group into "A, B, C" classes by Demand Value.

- Class A is items with high demand value (top 20 %)
- Class B items with medium demand value (next 40 %)
- Class C items with low demand value (bottom 40 %)
- Possibly also Class D for zero value = dead stock, but could include some insurance spares. Exclude these from percentages.

Focus most attention on improving the management of the Class A items.

20.23.7 Inventory Improvement Actions

- Eliminate stocks for items no longer in use.
- Retain stock of items which may be needed, even if they are old, slow moving or insurance items.
- Eliminate excessive stocks. Stocks above the (reorder level + reorder quantity) or MAX are normally excessive. Old stock can often deteriorate and cause problems when used.
- Reduce lead times, e.g., by faster freight service, or more frequent review.
- Use surface transport normally but air freight in an emergency.
- Consolidate stock holdings and/or stock level information across sites.
- Get the supplier to hold stock or send stock on consignment.
- Use a Just In Time call off system for steadily moving items.

20.24 Accounting for Inventory

Inventory is an asset. Fast moving inventory, with a turnover period of less than 1 year is a current asset, whereas slow moving inventory is a fixed asset. Categories of inventory include:

Current Assets

- Finished goods including distribution inventory
- Work in Process (WIP)
- Materials—for use in manufacture
- Consumables, e.g., fuels
- Spare parts of a fast moving nature.

Fixed Assets

- Spare parts, slow moving
- Repair parts, e.g., rotable assemblies
- Insurance spares—held just in case.

20.24.1 Inventory in the Balance Sheet

Inventory of all types occurs as an asset in the balance sheet. Inventory must be funded, that is, we have paid for it, and as it does not generate a return merely by sitting there, it is something which we should try to minimize, provided that we can do so without causing losses to appear elsewhere. This is why manufacturers try to minimize inventory through systems such as Just In Time and Lean.

20.24.2 Inventory in the Profit and Loss Account

The cost of the current asset inventory purchased in the year is part of the costs in the profit and loss statement, while the difference in the inventory value between the start and end of the year also appears in the profit and loss statement of company accounts.

$$\text{EBITDA} = \text{Revenue} - \text{Costs} + \text{Closing inventory}\,\$ - \text{Starting inventory}\,\$$$

In an operation which runs at a reasonably uniform pace, the difference between the values of closing and starting inventory will normally be small, so that the significance of changes in inventory value will not be great. However, an apparent profit arising primarily from an increase in the value of inventory over the year should be regarded with suspicion, as the inventory may ultimately not realize its quoted value. People have been known to lose their jobs when they were found out fudging the profit by overstating the value of inventory. Work-in-process inventory and capital developments partially completed, are areas where valuations can be hard to estimate.

20.24.3 Overstocking and Write Downs

For finished goods, an overstocked situation may lead to discounting of the price and hence to an inventory write down which will affect profits. A potential problem, relates to maintenance parts. Fast moving spares are treated as current assets,

but if they do not move as quickly as expected—as often happens—they can accumulate in value on the books. If it then turns out that they are subsequently worth much less than their purchase price, due perhaps to being obsolete, then a substantial write down, and hence loss of profit will occur.

As an example, consider a company which has a fleet of vehicles which uses a particular type of tire. The company buys a supply of tires for the vehicles. Tires are an expense item, that is, a current asset, and the value of tires in stock at the end of the year will contribute to profit. Later the vehicles are replaced by a different model which uses different tires. Tires of the original type which remain in stock will remain as a current asset, but may in fact have no value, in which case a write down will be required. On a small scale, this may be unimportant, but experience suggests that, when accumulated over many assets and a long period of time, the problem can become substantial. Management will be concerned at the cost and timing of a write down as it will reduce profit in the year in which it occurs.

A possible solution to the previous problem is to hold spares as capital items and depreciate them. However, another problem may then arise. Often, spares are charged out to a user, possibly an outside customer or an internal cost center, as they are taken from store. If spares are depreciated, they will be charged out at much less than their purchase price, and the decrease in value will be borne by our company or our cost center. To avoid this, we would need to have a policy of charging out spares at cost. Another thing is that if spares are depreciated, the accountants may want to write them off as of little or no value, when in fact they are essential to keep our major assets working.

Thus there are some tricky issues relating to accounting for slow moving spare parts.

20.25 So How Did We Win?

"Most of your war stories seem pretty negative, Pop," said Jock.

"Yes," said Pop. "In fact Hermann, our German storeman in Sennelager after the war, used to tell me that he couldn't understand how his side lost!

"One day though, a Polish bloke turned up at the store looking hot and bothered. He'd walked about 10 km from where his tank transporter had broken down. A brake jumper lead had failed and it wasn't safe to drive with the trailer brakes not working. He had the lead in his hand—he asked if we had a spare."

"We didn't have tank transporter spares and neither did anyone in the area. I took a look at the lead and figured that we could fix it temporarily by replacing the worn section with a piece of metal tube. I told the Polish driver to go over to the canteen and get something to eat and come back in an hour."

"I got Chalky White to turn a length of tube to the right size and to fix it into the lead with hose clips. We tested it on the compressed air machine and it was okay. The Polish driver was delighted, and we had a call later that day saying that he had got to his base safely and thanks."

"It was at a social barbecue later that Hermann said to me that that just wouldn't have happened in his army. They worked strictly in silos, and there was no way that his regiment would have let a foreigner near their stores, much less gone to the trouble of helping him out."

20.26 But Problems Remain

"Nothing that I learnt in my Operations Management class ever seems to work," Veronica complained one day at the water cooler.

I was going to ask what in particular she had in mind, but she went on seamlessly.

"The chlorinator has umpteen types of seal and a different one fails every time. They only cost a few dollars each but any one of them can bring the whole system to a grinding halt. Not only that, but you can't get them in this country, they have to be imported, and once we have a particular type in store we never need it again!"

I groaned sympathetically. She was feeling pretty stressed—the chlorinator was off-line again.

"I ordered a whole lot of seals for the annual shutdown, but guess what—some person (I think she said person) took a couple out of the store to use on the other line. Now were waiting for air-freight on $2 worth of items, at $20,000 an hour down-time."

"Hmm," I said, and edged away from the cooler.

……

A week or so later when things had calmed down, I asked Veronica what she meant about the Operations Management class.

"Well the lectures were all to do with the *standard deviation of the lead time demand* which seemed to be the answer to everything, but there is no chance of getting off first base with that in real life."

"The first problem is that the technicians want access to the stores 24 h per day 7 days per week. That cuts right across a stack of security issues. So the technicians "expense" a whole lot of stores that they think they might need and squirrel them away somewhere. This completely invalidates any demand data on the computer system."

"Another problem is that the people who work in the store nowadays, and the computer system people, know nothing about the equipment or about maintenance—it is all just part-numbers to them. Of course it's not their fault, but if only they *knew or cared* about what was going on in the plant it would make a lot of difference."

"One thing that we did at Widdecombe," I offered, "Was to employ ex-trades people in the store. They were all ex-mates of the technicians and understood the plant because they had worked there for years.

"In fact, there is a guy called Tom Cobbley who could do with a job right now, and who knows the refinery really well."

"Interesting," said Veronica, "I'll see what Human Resources says about that idea."

…….

"I think I know where the academics go wrong," I said, the next time I met Veronica in the tea room.

"Yes?" she said.

I reminded her about her comments about Operations Management lectures.

"What they do," I said, "is replace a simple problem with a harder one. For example, if you said to the storeman that it was okay to run out of stock of non-critical items occasionally, he could probably make a fair shot at the correct reorder level. But if you tell him to set the reorder level to the mean lead time demand plus 1.68 standard deviations then you have created a problem that he's not going to try to solve."

"I see what you mean," said Veronica, "but to be fair, the analytical types are trying to cope with thousands of items on some automatic basis. A human being can probably get a better answer if he has time to work on a particular item."

…….

"I thought that that consultant that we had was a complete idiot, but I can see what went wrong now," said Veronica a few weeks later.

She knew that I always lent a sympathetic ear to her stories.

"He spent ages setting the reorder levels on the automotive parts inventory, and as soon as he left we began to run out of parts."

"So was he an idiot or what?" I asked.

"As it happened, just after he left we decided to close the warehouses in New South Wales and Queensland and supply the dealers direct from the main store in Victoria. That completely changed all the demand data and made the reorder levels too low. That's why we ran out of parts."

"The consultant wanted to implement a forecasting system which would have updated the demand data, but apparently we were out of budget for consultants and that never happened."

"So what's happening now?" I asked.

"We're in a mess," she said.

…….

"I hear that you are leaving, Veronica"

"Yes, we're relocating to Perth. And by the way, I've just figured something out on the military maintenance contract."

"You always figure things out just too late … oops, sorry. Nothing secret, I hope"

"Not really. Peculiar though. We often had difficulty getting spare parts for the older army equipment until I met up with a secondhand dealer in Melbourne who always seemed to able to come up with the stuff. The thing I couldn't get was that it would always take him until 'next Thursday' to supply parts—it seemed odd."

"Then I realized that there was an Army Surplus sale at the depot every Tuesday. He was buying old stores from the Army, extracting what we needed and selling them back to us to sell back to the Army."

"So was he a crook or was he providing a valuable service?" I asked. But Veronica had hurried off into the sunset.

……

I saw Veronica about 6 months later at the Asset Management Conference.

"All running smoothly in Perth?" I asked.

"You'll like this one" she said. "I went to the electrical distribution branch's store to review their stock control procedures. As I arrived a truck pulled up with a couple of technicians in it. The storeman asked what they wanted and then directed them out the back to an open concrete area."—"Probably over on the far left," he shouted.

"They had come to look for replacement connectors for one of the older lines. I asked the storeman if they were easy to get."

"Impossible," he said. "They stopped making them 10 years ago, but some of the ones on the old wires are still usable. We never throw anything out."

"Do you have records of what you've got?" I asked.

"Naw-ugh," he said

"I thinking he was expressing a certain contempt for office wallahs."

"Well they had one thing right," I said, "The storeman knew the business."

20.27 Exercises

20.27.1 Self-Assessment Exercise 20.1

1. What are the aims of inventory management?
2. How are spare parts normally identified?
3. What is meant by:
   a. Dependent Demand
   b. Independent Demand
4. What is meant by:
   a. Current Stock Level
   b. Dues In
   c. Dues Out
   d. Net Level
   e. Back Order

20.27.2 Self-Assessment Exercise 20.2

1. What is meant by:
   a. Reorder Level and MIN
   b. Reorder Quantity
   c. MAX
   d. Lead Time
   e. Safety Stock
   f. Service Level
2. What factors influence stock holding policy for a slow moving item?

3. Explain the terms:
   a. Issue Multiple
   b. Shelf Life
   c. Supply Multiple
4. What is a target level reorder policy?

20.27.3 Reorder Level Exercise

Set a Reorder Level for each of the following items:

1. Item AB1234
   Average demand = 4.36 units/month
   Average lead time = 2 months
   Not critical (Answer 9)
2. Item SL456
   Average demand = 0.78 per month
   Average lead time = 14 days
   Critical (Answer 2)
3. Item C956-12
   Average demand = 12 per month
   Average lead time = 45 days
   Critical (Answer 23).

20.27.4 Reorder Quantity Exercise

Set a Reorder Quantity for each of the following items:

1. Item AQS90-78965
   Demand = 10 per month
   Supplied in boxes of 25 (Answer 25)
2. Item WSX567-321R
   Demand = 2 per month
   Option of individual purchase or in multiples of 50 at a discount (Answer 4).

20.27.5 Actual Order Decisions Exercises

20.27.5.1 Actual Reorder Decision 1

A stock controller has the following information regarding an item. What should he do?

Stock on Hand = 4
MIN = 8

MAX = 28
Supply Multiple = 5
Dues In = 20
Dues Out = 7
Special Demand = 6

What would you do?

Solution

$$\begin{aligned}\text{Net Level} &= \text{Stock} + \text{Dues In} - (\text{Dues Out} + \text{Special Demand})\\ &= 4 + 20 - (7 + 6)\\ &= 11\end{aligned}$$

This is greater than MIN so no action is needed.
Four items should be issued immediately to cover part of the dues out.
The Dues In should be expedited as there is a shortage right now.

20.27.5.2 Actual Reorder Decision Exercise 2

A stock controller has the following information regarding an item. What should he do?

Stock on Hand = 0
MIN = 6
MAX = 16
Supply Multiple = 5
Dues In = 0
Dues Out = 8
Special Demand = 0

What action should you take?

Solution

$$\begin{aligned}\text{Net Level} &= \text{Stock} + \text{Dues In} - (\text{Dues Out} + \text{Special Demand})\\ &= 0 + 0 - (8 + 0) = -8\end{aligned}$$

This is less than MIN so an order is needed.

Actual Order Qty = MAX − (–8) = 24
Round to 25.
Order 25.

20.27.6 Self-Assessment Exercise 20.1 Solution

1. *What are the aims of inventory management*?
   The primary aim of inventory management in the field of spares and consumables is to enable the meeting of requirements for equipment availability at minimum overall cost. This will involve:

   - Keeping service to the users at a reasonably high level
   - Keeping inventory investment reasonably low
   - Cost-effective purchasing.

   A balance must be struck between these conflicting factors.
   More basic aims of inventory management are to ensure that:

   - Stock identity, quantity and location are known;
   - Stock is secure;
   - Items are available and accessible when required;
   - Purchase orders are placed promptly;
   - Goods are received efficiently and effectively.

2. *How are spare parts normally identified*?
   Parts will be identified by means of a part number within the organization's inventory management system. The computer record will normally also contain the identification of the manufacturer and the manufacturer's part number.
3. *What is meant by*

   a. *Dependent Demand*
      Dependent demand is demand which can be estimated or planned, by time and quantity, from a production plan or a scheduled maintenance plan.
   b. *Independent Demand*
      Independent demand items are items for which demands occur on a variable basis, such as spare parts required for breakdown repairs.

4. *What is meant by*

   a. *Current Stock Level* The number of items physically in stock.
   b. *Dues In* Items ordered from a supplier but not yet delivered.
   c. *Dues Out* Items demanded by a user, but not yet issued.
   d. *Net Level* = Current Stock Level + Dues In − Dues Out.
   e. *Back Order* An item is on *backorder* or *backlogged* if it is not in stock, has already been ordered from a supplier, but the order has not yet been received.

20.27.7 Self-Assessment Exercise 20.2 Solution

1. *What is meant by*

   a. *Reorder Level and MIN*
   The reorder level or MIN is a value such that an order is placed when the net stock level falls below it.
   b. *Reorder Quantity*
   The reorder quantity is the guideline quantity to be ordered. This is typically a convenient handling quantity of 1–3 months demand, with possible consideration of quantity discounts.
   c. *Max*
   MAX is a guideline for the maximum amount of stock to be held. In practice it can be used as a reorder quantity guideline or as a target level. Typically set to a convenient handling quantity of 1–3 months demand with possible consideration of quantity discounts.
   d. *Lead Time*
   Lead time is the time taken from when the net level falls below the reorder level until the item becomes available for issue.
   e. *Safety Stock*
   The expected level of stock remaining at the end of the lead time is known as safety stock.
   f. *Service Level*
   The service level is the proportion of items supplied at the time required.

2. *What factors influence stock holding policy for a slow moving item*?

   a. Demand Rate.
   b. Item Cost.
   c. Shortage cost/Criticality.
   d. Lead Time.
   e. Safety and Environment.

3. *Explain the terms*

   a. *Issue Multiple*
   Items are issued in multiple quantities, for example spark plugs. The multiple may be different for different applications, e.g., four- or six-cylinder engine.
   b. *Shelf Life*
   The time for which an item can be stored before it deteriorates.
   c. *Supply Multiple*
   Supply is in quantity multiples which are convenient for packaging or transportation.

4. *What is a target level reorder policy*?
   In a target level policy, if at the time of ordering, the net level is below a set target level then sufficient is ordered to bring it up to the target level.