BRITISH STANDARD

BS 5192 :
Part 3 : 1993

Guide to production control

Part 3. Ordering methods

BSI STANDARDS

Committees responsible for this British Standard

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British Computer Society
British Production and Inventory Control Society
Chartered Institute of Management Accountants
EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
Institute of Logistics and Distribution Management
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Nottingham University
PERA International (Production Engineering Research Association)
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Contents

Foreword

This Part of BS 5192 has been prepared under the direction of the Quality, Management and Statistics Standards Committee.

The prime objective of production control is to help a company become more competitive and profitable. An effective production control function endeavours to fulfil this objective by keeping a balance between satisfying sales demand, achieving high plant utilization and maintaining low investment in stocks and work-in-progress. An optimum balance between these often conflicting objectives will only be achieved by a production control system designed to meet the specific needs of the company and run by well trained and dedicated staff.

BS 5192 is published in six Parts and gives comprehensive guidance in those areas that are considered essential for effective production control.

Part 1	*Introduction*: Scope of the guide, purpose of production control, relationship to other functions, technological changes, choosing the system to fit the business
Part 2	*Production programming*: Relationship to corporate and business programmes, planning techniques, master production scheduling, capacity planning
Part 3	*Ordering methods*: The various types of ordering and stock control systems, comparing the advantages of each for particular applications
Part 4	*Dispatching (shop-floor control)*: The methods of shop-floor production control and documentation involved and the increasing influence of computers
Part 5	*The relationship between control and other management functions*: The production control information flows in the organization, their generation, presentation, use and maintenance
Part 6	*Computer aided production control*: The application of computer software to the production control function

Throughout this standard use of the pronouns he, him and his is intended to be non-gender-specific.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Guide

Introduction

This Part of BS 5192 describes the second stage of production control (see figure 1). It covers the methods used to order the manufacture of components to be made in the company's workshops and to instruct the company's buyer concerning the deliveries of purchased parts and materials that are required from suppliers. An effective ordering system should avoid the pitfalls of excessive stock holding at one extreme or stock shortages at the other end of the scale.

1 Scope

This Part of BS 5192 gives guidance on ordering in all types of production industry ranging from the simplest to the most complicated case of engineering multi-product batch production. It describes the decisions to be made and the systems and methods that can ensure that these decisions are made efficiently. A number of ordering systems are described together with their applicability. The level of detail is sufficient to guide the readers on the choice of a system or systems appropriate to their industry.

2 References

2.1 Normative references

This Part of BS 5192 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this Part of BS 5192 only when incorporated in it by updating or revision.

2.2 Informative references

This Part of BS 5192 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 5192, the definitions given in BS 3138 : 1992, BS 5191 : 1975 and BS 5192 : Part 1 : 1993 apply.

4 The order

4.1 Purpose of an order

Ordering is the first stage in the process of executing the production programmes described in BS 5192 : Part 2. An order is an instruction to make or purchase an item contained in a product.

4.2 Push and pull ordering systems

There are two ways in which order action can be generated: either directly from a production programme or indirectly from a stock control system (to replenish stock as a result of stock being consumed). The former method is described as a push system because it pushes material into the manufacturing process to meet a demand and the latter is known as a pull system because material is pulled through the factory by demand.

4.3 Dependent and independent demand

Ordering systems can be further classified as those that treat demand as dependent and those that treat demand as independent. Manufactured products with some exceptions consist of two or more items. Manufacture depends upon bringing together all the items required to make the product in the right amounts and at the right time, i.e. the demand for each item is dependent. In non-manufacturing situations, for example in a finished goods warehouse, demand for each item is usually independent of the demand for every other item.

4.4 Choosing the right ordering system for the business

Ordering systems are described in clause **5** together with an explanation of their application to particular industries. Different situations require different solutions and it is quite common for businesses to use more than one system or a combination of systems. The latter are sometimes known as hybrid systems. It is essential that the user selects systems that are not over-complex yet are sufficiently resilient and comprehensive to meet all conditions of the particular operation.

4.5 Ordering decisions

4.5.1 *General*

Before an order can be placed the following decisions need to be taken:

a) what to order;

b) how much to order;

c) when to order;

d) when to deliver;

e) whether to make or buy.

These decisions are considered in **4.5.2** to **4.5.6**.

4.5.2 *What to order*

As explained in BS 5192 : Part 2, a production programme is a statement of what finished products are to be made, how many are needed and when they are required. A finished product, or end item as it is sometimes called, is a product that is offered for sale. It can be either a complete product, a service part or a byproduct. To translate the programme into action, an order should be raised for the finished product itself. This in turn

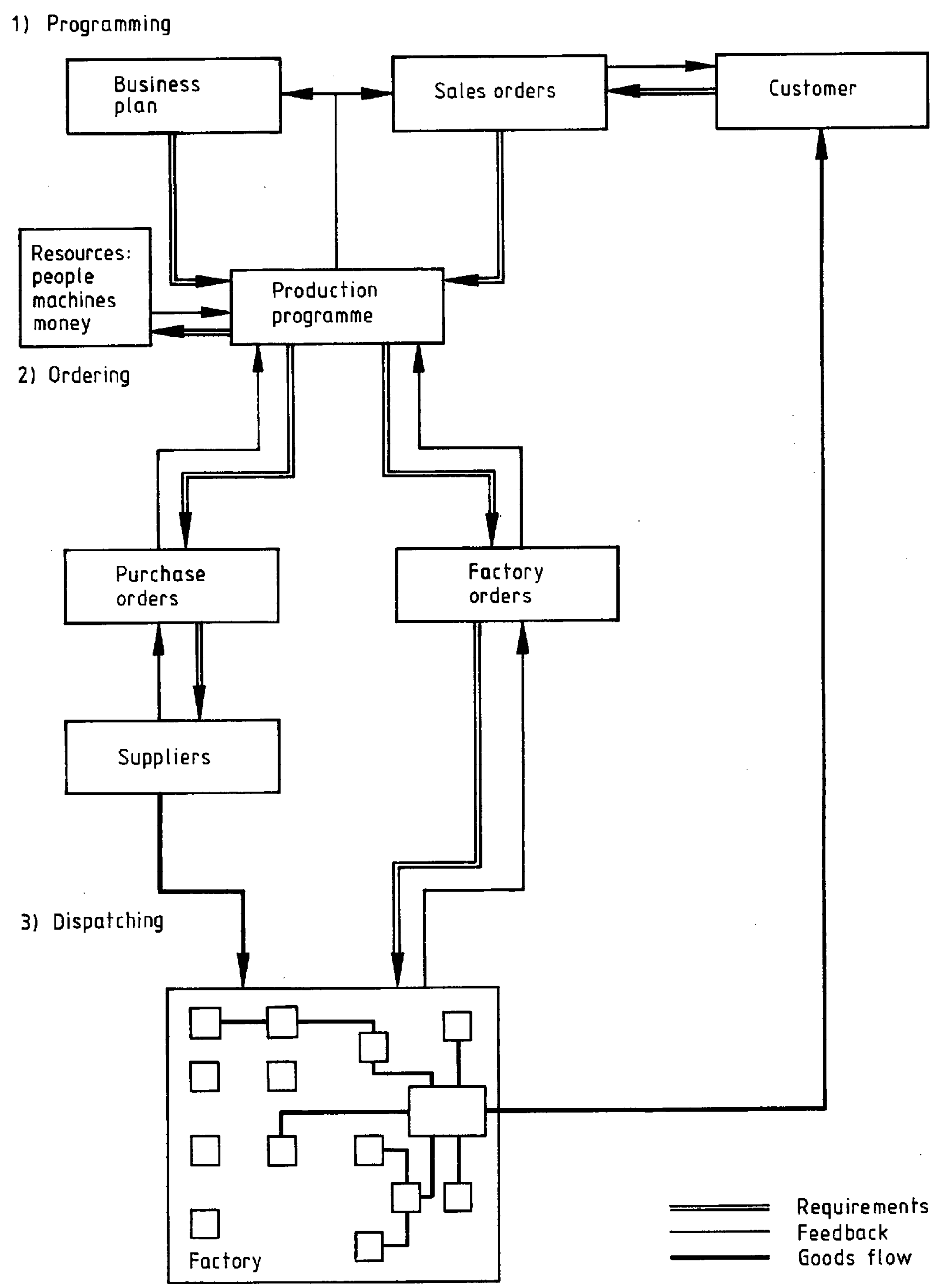


Figure 1. Stages of production control

will trigger demand for all the items that comprise the finished product. A product may comprise a single item of raw material, e.g. steel used to make a forging, or many thousands of items as in an aeroplane.

It is therefore necessary to know the content of the finished product and the way it is structured. Content defines the items and their amount and it is presented in a parts list, formula or specification. Structure defines the hierarchy in which the items are put together or assembled. A parts list that arranges the items in structured form is known as a bill of material. Figure 2 is an example of a bill of material.

4.5.3 How much to order

The bill of material shows the quantity of each item needed to make the next level up in the bill. For example in figure 2, three of item X are needed to make item C; two of item C which are needed to make item A. Therefore, six of item X are needed to make item A. The following are types of order quantities.

a) *Discrete order quantity.* The order quantity can be exactly that required to meet the immediate programme, i.e. if the programme calls for 10 of item A per week/day/hour, then the order for item X will be 60 per week/day/hour. This is called a discrete or lot-for-lot order quantity.

Should the item be common to more than one product, the quantity may be increased to aggregate concurrent requirements from several products. If there is surplus stock of the item arising from past orders, the quantity may be reduced by the amount surplus.

b) *Batch quantity.* The order quantity may be further adjusted by aggregating quantities from several time periods to take account of batching rules or policies set by production management.

The purpose of batching is to reduce the cost of administration and of setting up machines or, in the case of purchased items, to gain the benefit of purchase quantity discounts. However, the larger the batch size relative to immediate requirements, the greater the cost of holding stock. The most economic quantity is in theory the one for which the cost saving in the production process balances or equals the cost of holding stock. A mathematical relationship known as the economic order quantity formula can be used to calculate economic batch quantity. The formula is difficult to apply in practice because of the difficulty of determining accurate values for the cost factors used in the formula. Many businesses use instead simple rule-of-thumb methods for calculating batch size. Examples of such rules are 'the batch quantity is not to exceed one month's estimated usage' and 'the operation time for a batch is not to exceed one week'.

Similar rules apply for deciding whether or not to accept a quantity discount from a supplier. In purchasing, a situation can arise where it is expedient to order more than the immediate programme requires in order to take advantage of pending price increases or to avoid shortages arising from breakdowns in the source of supply. Such decisions should be made with great care as they can cause gross overstocking.

Further explanations of the way batch size may be calculated are given in clauses **6** to **9** which cover individual ordering systems.

Conventional cost accounting systems favour large batch sizes since set-up costs and purchase discounts are readily identifiable whereas stock holding costs are not easily quantified. However, large stock holdings impose severe penalties on the business in terms of high interest charges on capital tied up in stock, loss of flexibility, slow response to customer demand, increased risk from stock obsolescence and unproductive use of floor space.

These penalties are now widely recognized with the result that there is a move towards reducing batch sizes. This move has been helped by advances in production engineering which have made possible very significant reductions in plant set-up times.

4.5.4 *When to order*

The latest date by which an order for an item has to be issued to meet a programme demand is obtained by back scheduling from the completion date in the programme through the lead times of higher level items in the bill of material as well as the lead time of the item itself (see figure 3). See clause **6** for when to order in a stock control system.

Lead time is often difficult to estimate since it can vary from order to order depending on a number of circumstances: supply source, factory load, batch size, season, etc. Experience will help to determine a reasonable lead time under normal conditions.

In many factories parts spend on average 93 % of their manufacturing lead time queuing between operations, there is considerable scope for lead time reduction. In practice this often takes the form of expediting to achieve earlier delivery, but this can also delay other items. The emphasis should be on reduction of lead times by reducing queueing time for all items.

An order may be issued earlier than the latest date though this may cause delivery to be made earlier than required, especially with purchase orders, unless there are control procedures to prevent this happening.

4.5.5 *When to deliver*

Delivery date is the latest order date for the item plus the lead time of the order (see figure 3).

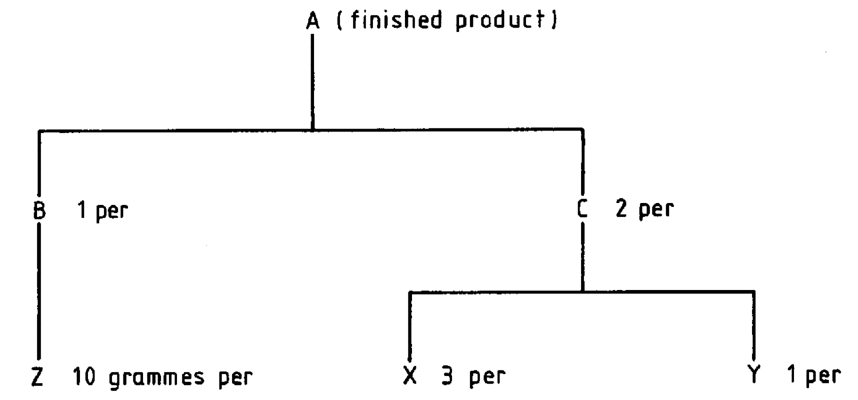


Figure 2. Bill of material

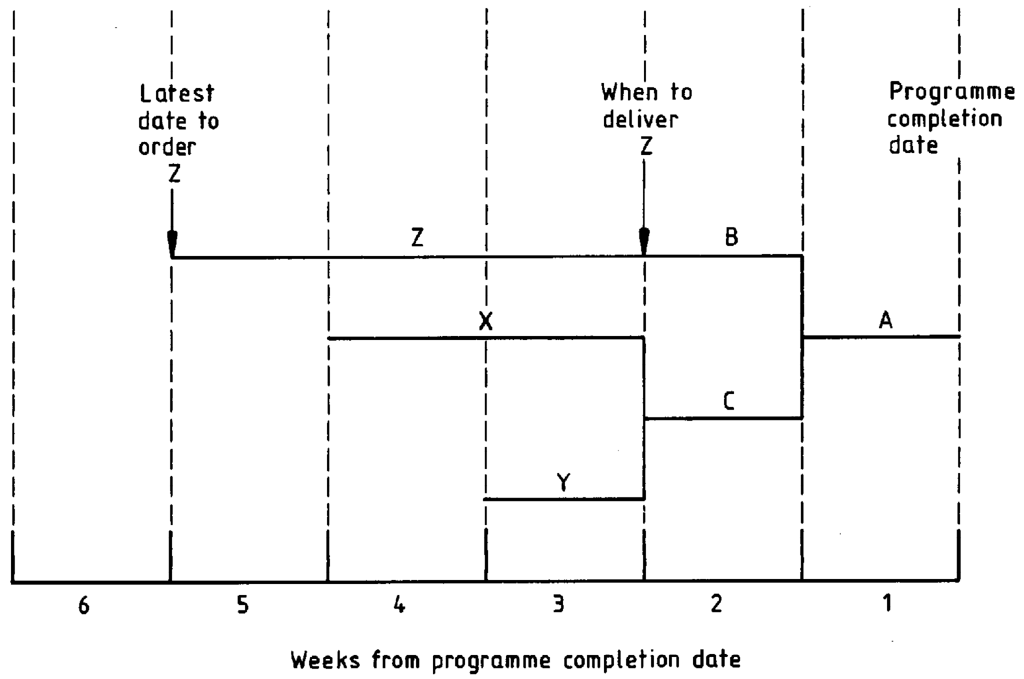


Figure 3. Example of when to order

4.5.6 *Whether to make or buy*

Make-or-buy decisions can broadly be divided into long term and short term. Long term decisions are generally dictated by manufacturing policy and the need to concentrate on what the business does best and most cost effectively. For example, a business may decide to concentrate on assembly and buy all materials and components, or a decision may be made not to replace capital equipment at the end of its useful life and to buy the items formerly produced on the equipment. However, even though purchasing may be more economical, a business may decide in some circumstances to retain or acquire a manufacturing facility for strategic reasons, for instance, to retain flexibility, to avoid dependence on outside sources or to give the customer a rapid service.

In the short term, a decision to buy is usually made in order to relieve a temporary overload and this kind of buying is known as subcontracting. Some businesses, as a matter of policy, deliberately limit internal capacity and subcontract the overload in peak periods in order to avoid having idle capacity.

4.6 Content of an order

4.6.1 *Factory orders*

The minimum information needed to execute an order in the factory is as follows:

a) a description of the item to be made or supplied;

b) a description of the material and parts it is to be made from and the amount;

c) the quantity to be made;

d) the date/time by which it is to be made;

e) the order identification.

Descriptions should be unambiguous and sufficiently comprehensive for the recipient to understand. Part numbers or codes should have a unique identity so that the item cannot be confused with any other. It is advisable in all documentation and computer displays to show both part number or code and description together as one can serve as a check against the other.

An order identification is essential. It is required for the purpose of tracking and progressing the order and in some cases for costing it.

The information may not necessarily appear in one document. For example, completion date may change between the time the order is raised and the time it is executed. This could be due to changing circumstances, such as an alteration in customer and shop floor priorities. To have to change completion dates on a mass of paperwork can be inconvenient and time consuming, but incorrect completion dates are misleading. It is therefore desirable to hold completion date information on a separate document. Such a document is sometimes known as a work-to list. It is issued to the shop-floor daily or weekly and tells shop supervision what jobs are to be executed that day or that week. The final assembly schedule described in BS 5192 : Part 2 is a particular form of the work-to list.

It is also advisable to have separate documentation for information about the material from which the item is to be made. This documentation is called a material requisition or, in the case of assembly operations, an assembly requisition, kit list or parts list. It gives the shop-floor authority to draw material from store. The documentation is separated from the rest of the order documentation and is used subsequently to update stock and costing records.

Items a) to e) are the essential information needed to handle a factory order; it should be remembered that this is the minimum needed. In practice much more information can be, and often is, added. The following information may also accompany an order:

1) routings (the sequence of operations which the item needs to follow);

2) production methods and times;

3) shop numbers, machine numbers, labour grades;

4) tool numbers;

5) engineering or technical specification;

6) job number, cost code, project number, sales order number.

It is customary to hold the permanent elements of the information such as production methods and engineering specifications in files on the shop-floor. This reduces the amount of paperwork that has to be reissued with each order.

4.6.2 *Purchase orders*

Creation of a purchase order normally involves two documents:

a) the purchase requisition;

b) the purchase order.

A purchase requisition is an internal document that is issued by the production or stock control function to the purchasing function. The requisition contains a description of the item to be purchased, the quantity and the required delivery date.

The purchase order is the contract between the buyer and supplier. In addition to the information given in the basic purchase requisition, it contains details of price and terms, location for delivery, technical specification or supplier's catalogue description, etc.

A purchase order may state a bulk quantity and ask for delivery to be phased over a period of time, e.g. so many per week. Alternatively, the purchase order may refer to a separate document, the call-off schedule, for delivery details. Call-off schedules are used extensively in high volume industries such as consumer goods. The purchase order states the estimated total quantity required over (say) a year so that the supplier can plan his production and reserve resources.

There are many variations of the call-off schedule, but a typical schedule would show required deliveries per week for the following four weeks, then per month over the following three months. Schedules are issued on a rolling basis with a period of overlap. The purchase order should state the buyer's liability in the event of total or partial cancellation. For instance in the above example, the buyer might accept full liability for the first two months of the schedule and liability for material only for the following two months. A substantial deficit in deliveries requested over the whole year compared to the total in the purchase order might call for a price revision.

4.7 Information feedback

An essential part of any ordering system is the means to feed back information about the state of the order in comparison to plan. An order that is issued, known also as an open order, should be closed when it is either fully or partially completed. An order that is not proceeded with should be cancelled and promptly removed from the system.

To facilitate the feedback of information, order documentation can be printed with bar coded or magnetic strip data, the former method being the most common. Data recorders situated in the factory read the information from the order documents directly into a computer system on completion of the order or a stage. This reduces the amount of data that has to be keyed in on completion, since, usually, the only variables that have to be entered are the quantities produced and rejected.

Methods for controlling and tracking orders are described in BS 5192 : Part 4.

4.8 Paperless systems

Paperless order systems are beginning to make an appearance though the completely paperless factory is still some way into the future. The following are two examples of paperless ordering so that applications that currently exist.

a) *Computer integrated manufacturing (CIM).* The planning department transmits order instructions via a computer system to a manufacturing cell in which the machines and the transfer equipment are controlled by computer.

b) *Electronic data interchange (EDI), linked to the supplier.* The buying department transmits orders via computer over the public telephone network into the supplier's computer system. Acknowledgements and invoices can be similarly transmitted.

5 Ordering systems

5.1 General

In most companies there are hundreds, or even thousands of different orders to be planned, issued and controlled. It would be impossible and also highly undesirable to treat each order as a separate independent problem.

Ordering systems are needed, first, to control the very large number of decisions to be made and, secondly, because the very detailed analysis necessary for treating each component separately as an entirely independent item can only lead to inefficiency.

5.2 Systems

The systems required are feedback control systems of the general type illustrated in figure 4.

The parameters are set for a given production requirement; examples of parameters are the order quantities, run quantities and transfer quantities which have already been examined.

The output variables represent the aims of the system. These are variables that the manager can only alter indirectly by changing the values of the parameters. Examples are product output, cost, profit, stock levels.

The input variables are those over which the manager has little or no control, but which have some effect on the outputs from the system. In different factories these may include such variables as the weather, the bank rate, the dollar exchange rate and the competition.

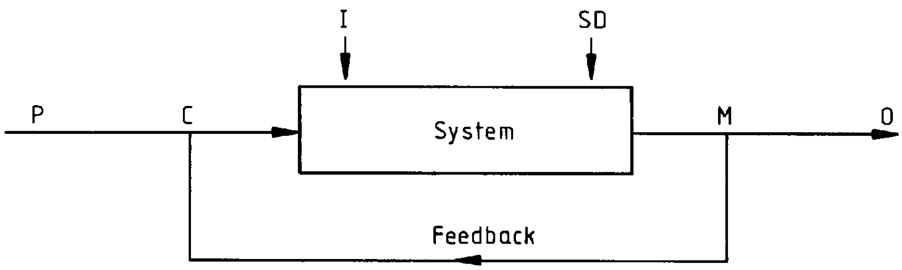
The characteristics of the system itself may also be changed by means of the system parameter settings. Changes to the system design will vary the way in which production relation parameters affect the output variable values.

The system is regulated by planning future values for the output variables and by issuing these plans in the form of executive orders to the factory. Production output is regulated, for example, by the issue of programmes and orders.

Control is the process of management by which achievement is constrained to follow plans. System output is controlled by monitoring, comparing the output with the plans, and feeding back of information about significant variances, so that parameter values can be changed to bring achievement back into line with the plans.

An important aspect of feedback control systems is that in some circumstances they can be unstable and go out of control. Much of the theory of feedback control systems stems from work done in the engineering field on such apparently diverse subjects as speed governors, position control servo mechanisms or electronic feedback amplifiers. Here the instability leads to a phenomenon frequently called hunting. This means that the output quantity does not settle at the required value but continually oscillates between values above and below what is required.

For further details see J.W. Forrester, *Industrial Dynamics* [1].



Key

P, parameter;

SD, system design parameters;

O, output variable;

M, monitoring;

I, uncontrollable input;

C, controller.

Figure 4. A feedback system

5.3 Objectives in system design

In designing the ordering system there are a number of major objectives including the following:

a) *Survival.* Survival is normally the first objective in system design. To survive, the company should, among other things, make a profit or maintain its capital in some other way. Survival depends on management efficiency as well as on system design.

b) *Sensitivity.* Sensitivity is a measure of the speed of system response to changes in output variable value, induced by changes in parameter value.

c) *Controllability.* Controllability is a measure of the effectiveness with which a system can be controlled. Do appropriate changes in parameter values have a positive and predictable effect on the output variables and how quickly do they act? Controllability is partly a function of sensitivity.

d) *Flexibility.* Flexibility is a measure of the ability of the system to respond to change. How quickly and efficiently can it respond for example to changes in product design and changes in market demand for the product?

e) *Productivity.* Productivity is the ratio of system output to the input of resources. The word is normally reserved for the productivity of people, or of machines.

f) *Profitability.* Profitability can be described as the productivity of capital. It is a measure of the money return obtained with a given investment.

NOTE 1. It used to be thought that it was impossible to achieve all these objectives together and that it was necessary in each case to choose between them. Recent research has indicated that they are much more compatible than used to be thought and that they all require similar basic system design features.

NOTE 2. Ordering systems are only subsystems of production control systems and production control systems are only subsystems of production systems. The best results in system design require a hierarchical, holistic approach, that starts with the design of a good total system.

5.4 Types of ordering system

Several types of ordering system are discussed in clauses **6** to **9**. These systems operate in different ways according to how they handle the various criteria for making a decision to place an order. The main criteria are as follows.

a) *Bill of material link.* Systems either use this link to trigger new orders (dependent demand) or they do not (independent demand).

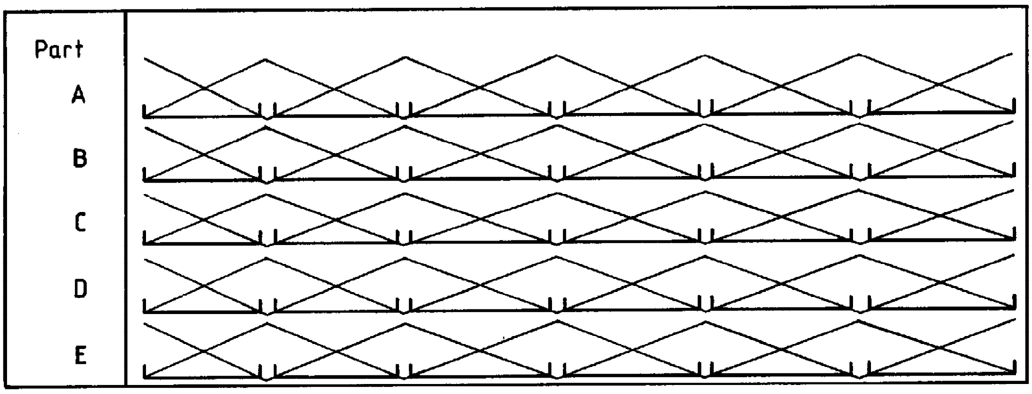
b) *Order status.* Orders may be triggered by firm sales orders that pull the necessary lower-level orders throughout the factory and also by forecast sales orders that cause the lower-level orders to be pushed through the factory to meet the expected sale.

c) *Order release schedule.* Orders may be released in batches to the factory at regular, fixed intervals through the year (a single-cycle system) and they may also be released as dictated by some other criterion at any time (a multi-cycle system). (See figure 5.)

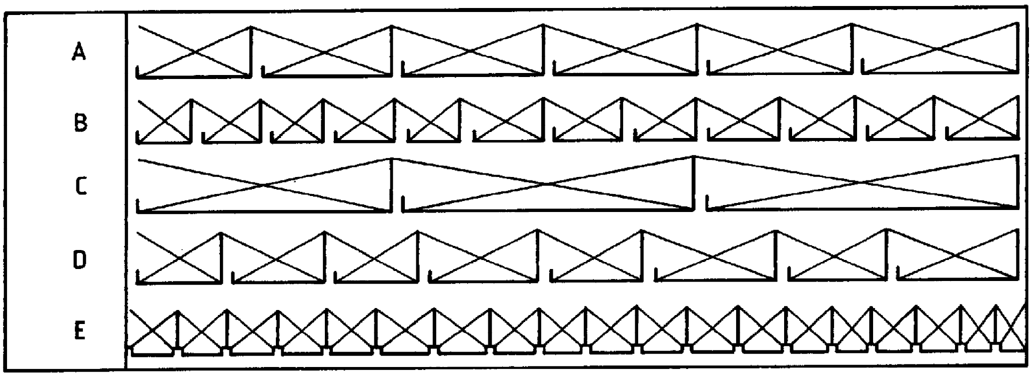
d) *Scheduling.* Orders may be triggered by calculating the release date back from the sales order due-date and also forward from the sales order receipt date.

e) *Capacity.* Orders may be scheduled by taking into account the available capacity on the next operation's finite capacity and also by ignoring it and using infinite capacity scheduling.

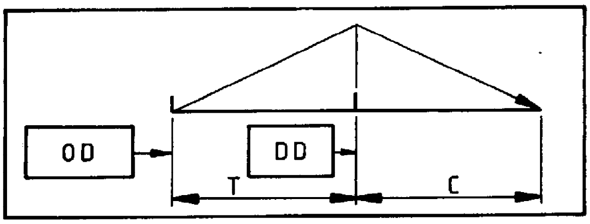
Table 1 indicates how the standard ordering systems handle the criteria listed in items a) to e).



1 Single-phase, single-cycle



2 Multi-phase, multi-cycle



Key

OD = Order date

DD = Due-date

T = Cycle time

C = Consumption time

Figure 5. Single- and multi-cycle ordering

Table 1. Standard ordering system classifications

Ordering system	Type	Stock control	PBC	MRP	Kanban	OPT®[1]
Bill of material link	Dependent	X	Y	Y	Y	Y
	Independent	Y	O	O	O	O
Order status	Pull	O	Y	MTO	Y	MTO
	Push	Y	X	MTS	X	MTS
Order release schedule	Single-cycle	FIR	Y	O	X	O
	Multi-cycle	FOQ	X	Y	Y	Y
Scheduling	Back	—	—	Y	—	C
	Forward	—	—	O	—	
Capacity	Finite	—	—	O	—	C
	infinite	—	—	Y	—	

Key

X, does not operate in this style;
Y, operates in this style;
O, can be made to operate in this style;
C, combines both styles;
MTO, make-to-order;
MTS, make-to-stock;
FIR, fixed interval re-order;
FOQ, fixed order quantity;
PBC, period batch control;
MRP, material requirements planning;
OPT, optimized production technology.

[1] OPT is the registered name given both to a manufacturing concept and a proprietry softwate system developed in the early 1980s. This does not constitute an endorsement by BSI of the system.

5.5 Related control systems

Ordering systems depend for their efficiency on three main subsystems, known as the controls.

a) *Progressing*. This is a feedback control system that attempts to constrain the production output to follow the plans in the production programmes, shop orders and purchase requisitions.

b) *Inventory control*. This is a feedback control system in which actual stock locations and levels are measured and compared with planned stock, so that the investment in stocks and work in progress can be controlled. The design of the production system and the way it is managed have a major effect on the investment in stocks and work in progress.

c) *Loading*. This is a feedback control system that compares load with capacity and feeds back information to the manager about overload and underload. Loading is important to production control because it makes it possible to determine whether there is sufficient capacity to complete the orders that it issues. Also, it provides the information needed for capacity planning. The short term methods for changing capacity levels in particular, such as overtime, shift working and subcontracting, can only be planned efficiently if accurate data are available about the capacity and load. Longer term projections of the load are used to make the decision on whether to change capacity levels (manpower and/or machine).

6 Stock control systems

6.1 General

To aid understanding of stock control systems it is necessary to explain why stock needs to be held. Stock costs money to hold. It takes up floor space, it has to be made secure, stored and counted, it becomes obsolete as designs and fashions change, it deteriorates, it ties up capital on which interest has to be paid or that could be used more effectively elsewhere in the business. It adds no value to the product.

Ideally, a manufacturer would obtain material, convert it into a product and sell the product without the need to hold stock. This is a goal which many Japanese companies are successful at achieving.

Nevertheless, there are three reasons for holding stock. First, to protect the manufacturing process against uncertainities in the supply chain, e.g. unreliable suppliers, manpower shortage and absenteeism, machine breakdown and defects; secondly, to reduce costs by buying or making in a larger batch quantity than is necessary to meet immediate production requirements and thirdly, to provide a service to customers by supplying products from stock instead of making to order.

Every reason advanced for holding stock should be reviewed critically to test its validity. It is often possible to reduce or even eliminate stocks by changing manufacturing methods, improving communications with suppliers or by better management information.

Table 2 contains details of the common stock categories found in manufacturing together with their purpose and suggestions for the reduction of stock.

The categories of stock detailed in table 2 may be controlled by a number of types of stock control system as described in **6.2** to **6.5**. Table 3 contains a summary of these systems and the applications for which they are appropriate.

Table 2. Common stock categories

Stock category	Purpose	Suggested ways to reduce stock
Purchased raw material and goods	a) To provide protection against unreliable supplier b) To gain the benefit of quantity discounts	a) Improve communications with supplier, or find new supplier, if possible b) Check that the benefits of quantity discounts outweigh the penalties of extra stock holding costs
Inter-process stock	a) To provide protection against machine failure, absenteeism, quality rejects b) Batch production to reduce process set-up cost	a) Improve machine maintenance, labour relations and quality b) Endeavour to cut set-up time by improving methods
Warehouse and distribution stocks	To provide a service to customers	a) All the preceding steps improve customer service by cutting lead time and making production more responsive to customers' demands b) If possible reduce end product variety by making in modular form and assembling to order
Strategic stocks	a) To take advantage of commodity prices b) To protect against a breakdown in supply c) To protect against long lead times	All such decisions should be taken with great care and at the highest level
Service stock	To provide after sales service and spare parts	Monitor the rate of call-off, particularly of obsolete products. Consider making parts to order rather than holding stock

Table 3. Stock control applications

System	Applications
Fixed order quantity	Finished goods stores Warehouse stocks Service and spares stock
2/3 bin (fixed order quantity)	Low value items (C items)
Fixed order quantity with reservations	Applications same as above two systems, but used in situations where an early warning of demands is important
Fixed order quantity with forecast demand based on explosion of production plan	Sometimes used to control production stocks as an alternative to dependent demand systems
Based stock and kanban	Assembly or flow line stocks
Fixed interval re-order	Retail Housekeeping stocks, e.g. maintenance stores, small tools, paints, oils
Min-max	Used instead of a fixed order quantity system or a fixed interval re-order system in situations where it is important to place a maximum limit on the level of stock that may be carried

6.2 Basic stock control systems

Stock control systems are, in general, independent pull systems. They are independent because the replenishment of each stock item is treated independently from all others. They are pull systems because material is pulled from the stock by demand. Some versions endeavour to provide links between the stocked items as well as means to take account of forward planned demand, and could therefore be regarded as semi-dependent push systems; **6.5** describes some of these versions.

Stock control is the oldest form of replenishment system and is used extensively by the retail and distribution industries. In manufacturing it has been superseded to a large extent by dependent push systems, though stock control systems still have a number of useful manufacturing applications.

There are two basic stock control systems:

a) fixed order quantity;

b) fixed interval re-order.

6.3 Fixed order quantity system

6.3.1 *Re-order level and lead time*

The system is also known as a re-order level (ROL), re-order quantity (ROQ) or a re-order point (ROP) system. The main features of the system are shown in figure **6** which shows stock consumption over time. In this system, a fixed quantity replenishment order is placed whenever the stock falls to or below a predetermined re-order level. This level equals the quantity forecast to be consumed during the estimated time to replenish stock (the lead time). As figure 6 shows, the re-order level should be revised whenever forecast usage and/or lead time change significantly.

Lead time should also include time needed to create and issue the order as well as the actual time to manufacture or purchase a product. An explanation of lead time is given in **4.5**. The other parameters that occur in a fixed order quantity system are described in **6.3.2** to **6.3.5**.

The re-order level should include actual physical stock plus any outstanding replenishment orders due for delivery. See also **6.5.2** for systems where stock is reserved or allocated.

6.3.2 *Safety stock*

If consumption and lead time estimates are accurate, stock will fall to zero just at the point when the replenishment order is delivered. Because such consistent accuracy is difficult to achieve, a safety or buffer stock is usually carried to reduce the risk of a stock-out occurring in the event of actual consumption exceeding the forecast or the lead time being longer than predicted. The re-order level then becomes forecast consumption during the lead time plus safety stock.

The amount of safety stock to be carried depends on the following.

a) *Desired level of service.* Figure 7 illustrates the relationship between service level and the cost of providing that service. Note that 100 % service level is an impossibility. The amount of safety stock needed to provide protection against stock-outs increases relative to the desired service level. A business should set a stocking policy that balances the marketing benefits of providing a high service level against the cost of providing the service.

b) *Variability of demand and frequency of ordering.* Items that are difficult to forecast or have a highly random demand pattern require more safety stock than those with a steady demand. The amount of safety stock is also related to the frequency of ordering since forecasts become less accurate as their time span

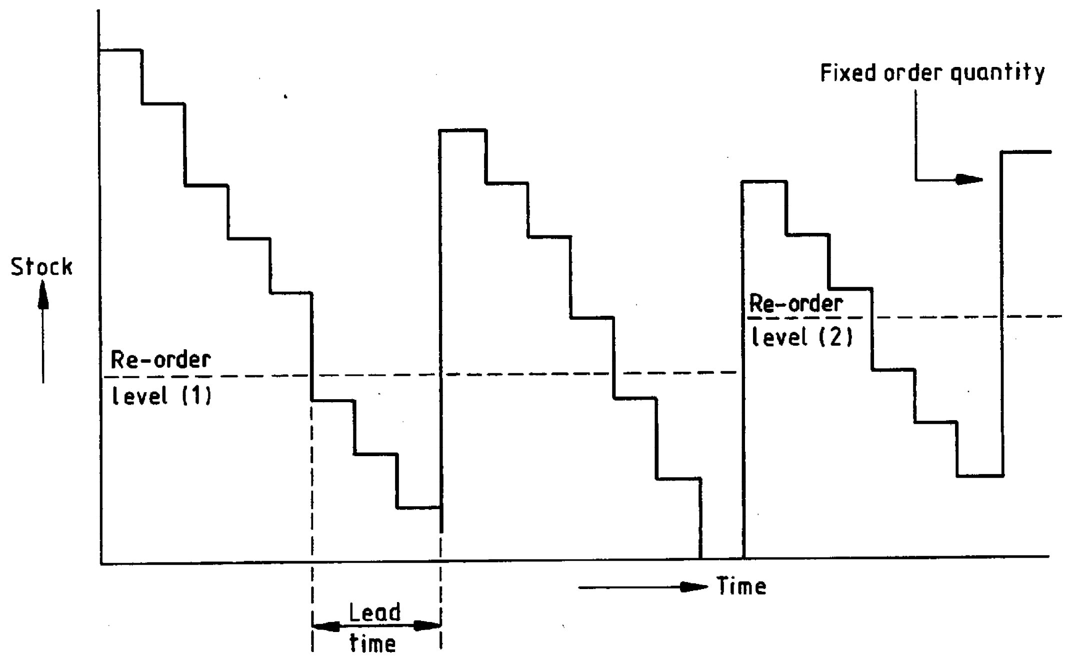


Figure 6. Fixed order quantity system

increases. However, for a given level of safety stock the probability of stock-out due to operating below the re-order level increases with ordering frequency. In order to provide the same protection at high ordering frequency the safety stock level therefore needs to be increased. (See clause **5** of BS 5729 : Part 3 : 1983.)

c) *Variability in lead time and length of lead time*. Uncertainty or variability in lead time increases safety stock. Also, the longer the lead time, the less accurate the forecast and hence the greater amount of safety stock that has to be carried.

There are a number of statistical methods for calculating safety stock, but it is worth remembering that the amount of protection required also depends upon the following two factors:

1) the importance of the item and how urgently it is needed;

2) the length of lead time.

For instance, if an item can be replenished within 48 h and this is an acceptable time for meeting a demand, it may be unnecessary to carry safety stock. If the demand pattern for an item is very random, or lumpy as it is sometimes called, there may be a case for categorizing the item as to be made to order.

Instead of holding a fixed safety stock quantity, another way of providing protection against stock-outs is to express safety stock in terms of time periods of forecast usage. For example, if the forecast usage over four weeks is 80, a re-order level set at 120 will provide a two week safety stock.

6.3.3 *Order quantity*

Methods of determining the order quantity are described in **4.5.3**. Further information about methods of calculating order quantity is contained in clause **3** of BS 5729 : Part 3 : 1983.

6.3.4 *Forecast consumption*

Forecasts may be based upon historical data, future predictions of requirements or a combination of both. Forecasting methods range from simple extrapolation of historical data on a month to month or year to year basis to complex statistical formulae which take account of demand pattern, long term trends and seasonal demand and which can identify and discard abnormal demands.

Until the advent of computers, advanced statistical techniques were mainly confined to text book theory because of the practical difficulty of applying them to manual systems. Care should be taken when using statistical techniques; they should be thoroughly tested, if possible on actual

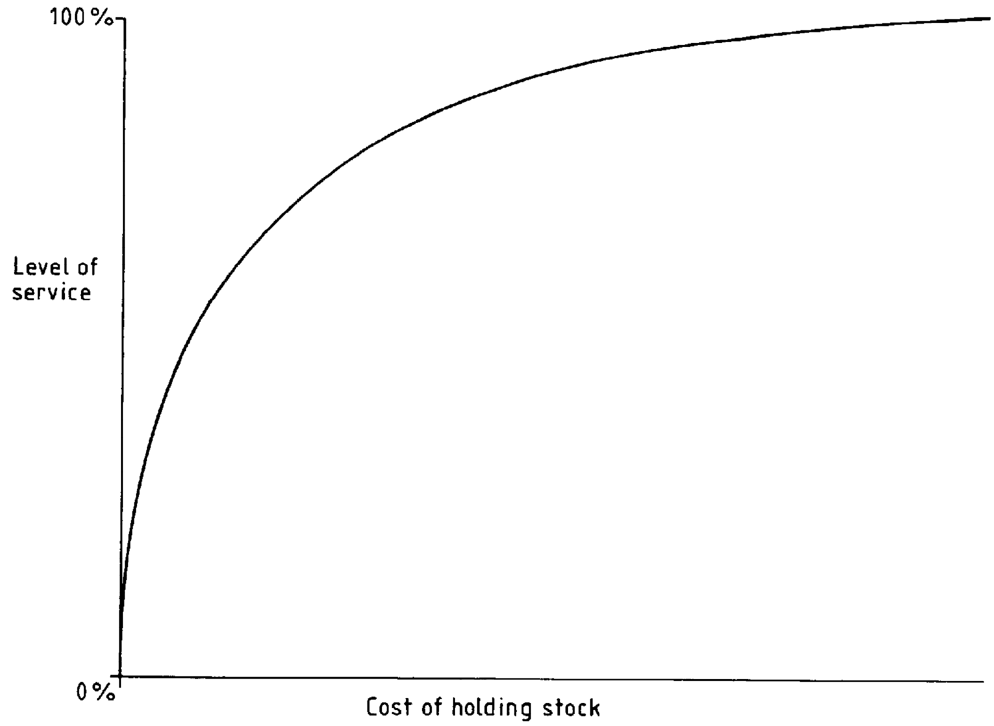


Figure 7. Service level

sample data, to check that the output corresponds to reality before they go live. Thereafter, it is advisable to monitor performance periodically to ensure that conditions have not changed and that the assumptions on which the original system was set up are still valid.

Computer forecasting systems should allow the user to view the forecast on a screen before applying it and to adjust the forecast manually if information external to the system makes this desirable. For example changes in forecast may be prompted by the mounting of an adveritising campaign, the introduction of a new product or the phasing out of an old one.

For further information about forecasting systems, refer to BS 5729 : Part 2.

6.3.5 ***Performance criteria***

The effectiveness of a stock control system is measured by:

a) the incidence of stock-outs; and

b) stock turnover.

The incidence of stock-outs is the number of occasions when a demand cannot be satisfied from stock. In some organizations, performance is measured by the number of demands that are not met within a specified period of time, e.g. number of demands not met within 48 h, one week, two weeks, longer than two weeks and so forth. The term backorder is sometimes used in place of stock-out to define an immediate or past due unsatisfied demand.

Stock turn is obtained by dividing the total turnover of stock by the value of the stock holding. For example, if the annual cost of sales is £1 million and the value of the stocks is £200 000, the stock turn is 5, i.e. stocks are said to turnover on average five times a year. Concealed within that overall figure are items that do not move at all and others that move more rapidly. It is therefore advisable, when carrying out an extensive investigation to subdivide stocks into their individual categories, e.g. raw materials, work-in-progress and to measure the stock turns of each.

Care should be taken to express stock value and turnover in the same units, e.g. standard costs and cost of sales, but not selling price.

In seasonal businesses, it is often informative to express stock value in terms of forecast weeks sales. For example, a toy manufacturer may always aim to hold four weeks of finished stock. Before Christmas, this may represent 40 % of annual turnover whilst in January the same four weeks stock holding might only amount to 5 % of annual turnover.

6.4 Fixed interval re-order systems

Figure 8 shows the main features of a fixed interval re-order system, also known as a periodic review system. An item is reviewed at regular intervals and, if necessary, a replenishment order is placed to bring the stock up to a predetermined level, generally known as the maximum stock level. This level is equal to the forecast consumption during the replenishment lead time plus one review period. A safety stock may be added to this quantity.

The system is generally used in situations where lead times are short and where the review period is also short, i.e. daily, weekly or a month at the most. It is used extensively in retailing and distribution, but has few applications in manufacturing industry.

6.5 Versions of basic systems

6.5.1 ***ABC analysis***

ABC analysis is not a stock control system but a technique for categorizing stock in such a way that it can be used to establish the most suitable form of control to apply to each category.

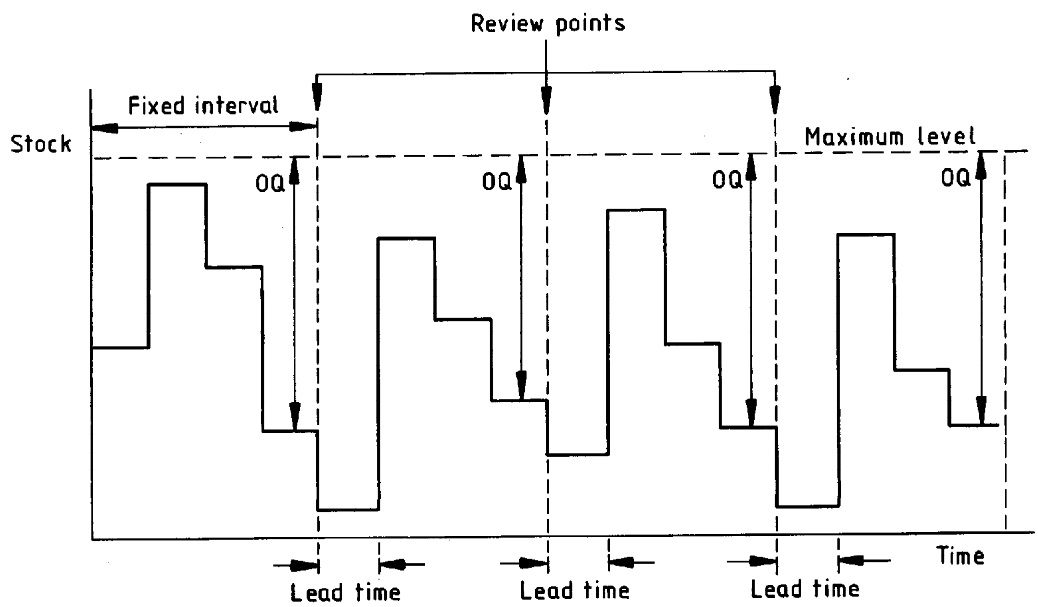
In everyday situations, it is often found that two characteristics are related to one another exponentially. For example, it might be found that in a particular country 80 % of the population occupy 20 % of the land, or in a certain factory 20 % of the orders take up 80 % of the production controller's time. It is possible to apply this 80/20 rule, or Pareto analysis as it is sometimes called, to the analysis of stock items, if it is found that their consumption follows a similar pattern. For instance, in many companies, 20 % of the materials consumed account for 80 % of the total annual turnover, and the remaining 80 % only 20 % of the turnover.

Figure 9 shows how the principle may be applied to the classification of stocks into A, B and C categories. The data from which this figure is derived are contained in table 4. In the example, 40 A items or 2 ½ % of the total number comprise 70 % of annual turnover, and 45 B items comprise a further 20 %. The remaining 95 % (1600 items) account for only 10 % of turnover. Most computer stock control systems can readily produce an ABC analysis provided unit costs are on file.

The steps involved in creating an ABC analysis, as shown in table 4 are as follows.

a) The unit cost of each stock item is multipled either by its historical annual usage or, preferably, by its next year's planned usage to obtain its usage value.

b) The items are ranked in descending order of usage value. When this exercise is first performed, a number of items at the end of the list will probably have zero value. This is because either unit costs have not been established for them, or they have not moved in the past year or they have no forward planned requirement. Such items should be investigated and they should either be costed or removed from active stock if they are redundant.



Key

OQ is the order quantity.

Figure 8. Fixed interval re-order system

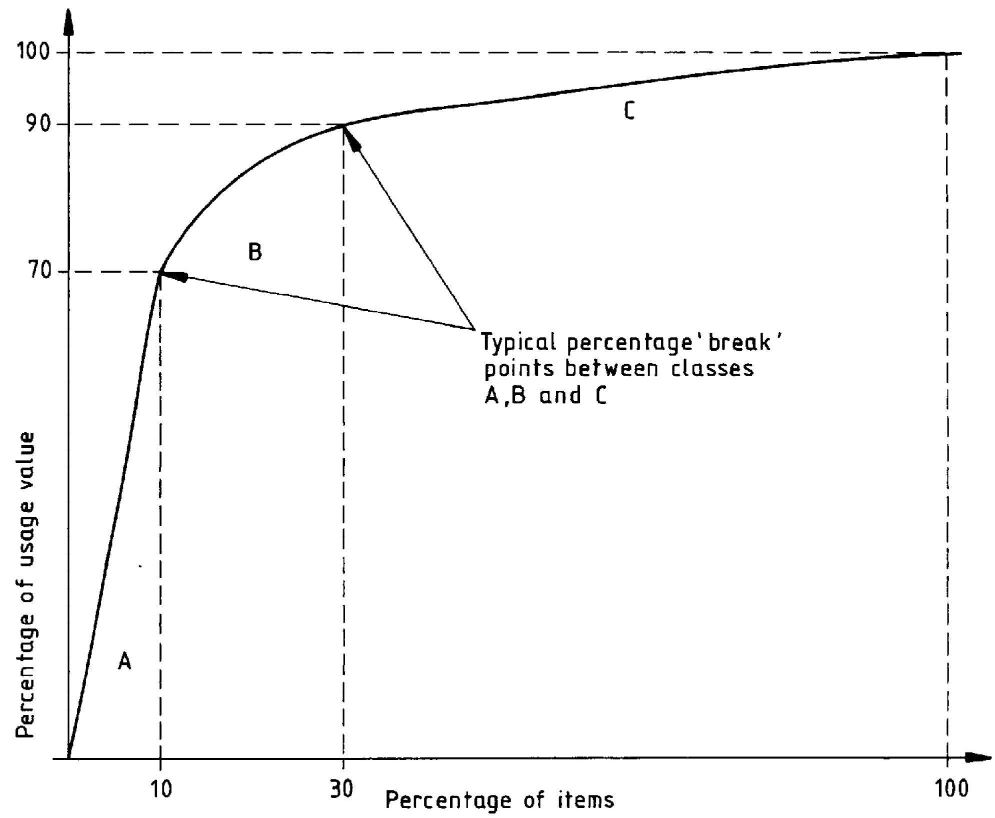


Figure 9. ABC analysis

c) Starting with the highest usage value item, the accumulated total usage value is listed item by item. The total accumulated value is the annual historical or planned turnover of the stock.

d) The usage value of each item is expressed as a percentage of the turnover and the accumulated percentage is calculated for each item.

e) A line is drawn at the item with 70 % accumulated turnover (in the example this is the 40th item). The items above this line are classified as A items.

f) A line is drawn at the item that represents 90 % of accumulated turnover (number 85). Items between the two lines are B items and those below are C items.

ABC analysis is used to set control policies for each stock category. For example, A items, since they are few in number and represent a large proportion of total value, can be individually controlled. The same may apply to a lesser degree to B items, whilst C items are controlled very simply. A items may be ordered once a week or month, B items every three months and C items every six months. It is common to use material requirements planning (MRP) or similar dependent demand type system to control A and B items and a less sophisticated system for C items, for instance, a two bin system (see **6.5.3**).

6.5.2 ***Planned demand***

In a manufacturing environment, historical data are often a poor indication of future demand. Stock control systems based on historical data are slow to react to engineering changes, revised production programmes and the introduction or phasing out of products. This deficiency can be partially overcome by basing the forecast on planned forward demand and setting re-order levels accordingly. This is done by exploding the production programme to obtain the total planned requirements of each item for say the next month or three months.

Another method is to take the phased demands from the production programme and to use them to allocate or reserve stock, for example, a week before it is required. This gives the system prior warning of future demands but has two disadvantages. It doubles the number of entries in the system, and it causes confusion if programmes change between making the allocation and issue: de-allocations have to be made. Allocations should never, therefore, be made too far ahead of the actual requirement. (See figure 10.)

Table 4. Typical ABC analysis of stock using computer calculations

Item	Part number	Description	Quantity	Value	Accumulated value	Total value	Accumulated total value
						%	%
1	87500263	PRT mech 400LPM	191	479639.20	479639.20	12.830326	12.830326
2	87500510	High speed print mech	71	329804.94	809444.14	8.822267	21.652593
3	87500506	Mag tape unit 9T mech	183	314880.78	1124324.92	8.423046	30.075639
4	87500215	PIR mech 600LPM CDC	86	259126.60	1383451.52	6.931624	37.007264
5	81004640	PC board, 8K memory	540	128271.06	1511722.58	3.431245	40.438509
6	87500045	MT trans	70	126164.50	1637887.08	3.374895	43.813403
7	81002552	PCB	4369	84042.08	1721929.16	2.248122	46.061525
8	81004303	Board assembly	175	60179.18	1782108.34	1.609790	47.671315
9	87500426	Card punch 50 Hz	25	54838.88	1836947.22	1.466937	49.138253
10	67000999	Frame controller	357	50890.35	1887837.57	1.361314	50.499567
etc.							
32	67001883	Frame bysine	175	19219.76	2471592.22	0.514128	66.114977
33	81002291	Board assembly	357	17805.38	2489397.60	0.476293	66.591270
34	81002183	Board assembly	357	17580.47	2506978.07	0.470277	67.061547
35	81002212	Board assembly	532	17042.89	2524020.96	0.455897	67.517443
36	81001690	Board assembly	318	17028.90	2541049.86	0.455522	67.972966
37	81002273	Board assembly	357	16421.93	2557471.79	0.439286	68.412251
38	81002284	Board assembly	357	15248.90	2572720.69	0.407907	68.820159
39	67001000	Main frame	86	15149.14	2587869.83	0.405239	69.225398
40	81002252	Board assembly	357	14555.43	2602425.26	0.389357	69.614755
40 items = 70 % of turnover (A items)							
41	81004710	PC board	357	14461.71	2616886.97	0.386850	70.001605
42	76162400	Power supply 50 Hz	191	13625.94	2630512.91	0.364493	70.366098
43	81004260	Board assembly	175	13336.58	2643849.40	0.356753	70.722851
44	82361535	Cable assembly	458	13305.91	2657155.40	0.355932	71.078783
45	81001650	Board asembly	318	12571.34	2669726.74	0.336283	71.415066
46	81002231	Board assembly	357	12549.98	2682276.72	0.335711	71.750777
47	81002425	PCB	229	12475.78	2694752.50	0.333727	72.084504
48	81001420	Board assembly	318	12427.76	2707180.26	0.332442	72.416946
49	81002343	Board assembly	257	12286.27	2719466.53	0.328657	72.745603
50	81004700	PC board	357	12283.83	2731750.36	0.328592	73.074195
etc.							
80	67661985	Fan	216	1997.14	3353169.70	0.053423	89.697133
81	67000691	Front cover	196	1993.32	3355163.02	0.053321	89.750455
82	51128800	Transistor	568	1985.73	3357148.75	0.053118	89.803573
83	67000704	Chassis mtg.	298	1984.23	3359132.98	0.053078	89.856651
84	67001183	Cont panel	439	1958.82	3361091.80	0.052398	89.909049
85	24000001	3 ring binder	1000	1955.00	3363046.80	0.052296	89.961345
85 items = 90 % of turnover (B items)							
86	67000096	Bkt connector 20/.75	1048	1904.22	3364951.02	0.050938	90.012283
87	81002572	Board assembly	86	1851.15	3366802.17	0.049518	90.061801
88	67000708	Logic frame	318	1828.50	3368630.67	0.048912	90.110714
89	52312148	A1 elect caps 160000U	363	1806.65	3370437.32	0.048328	90.159041
etc.							
223	67001294	Front panel	171	1406.05	3424289.50	0.037612	91.599585
224	67000602	Cover plate mtg	357	1395.87	3425685.37	0.037339	91.636924
225	24000002	Multi-ring binder	600	1393.80	3427079.17	0.037284	91.674208
226	67001893	Plenum logic	175	1384.60	3428463.77	0.037038	91.711246
227	67001892	Plenum logic	175	1384.60	3429848.37	0.037038	91.748284
228	56215130	Ring term	2800	1368.36	3431216.73	0.036604	91.784888
229	62541000	'O' ring	1832	1360.08	3432576.81	0.036382	91.821270
etc. to 1685 items							

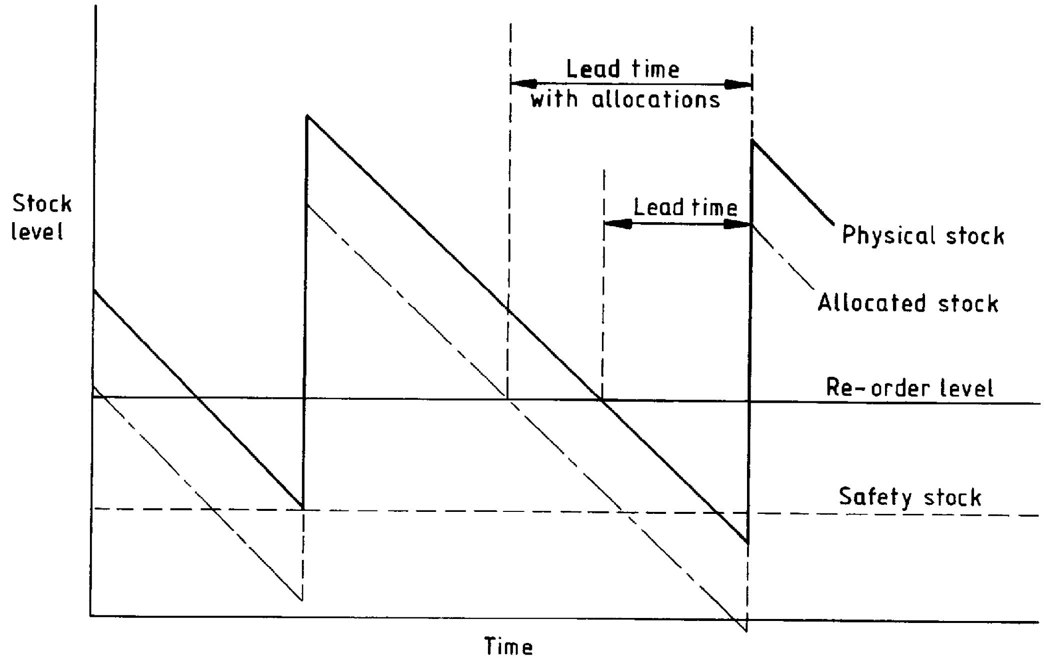


Figure 10. Fixed order quantity with allocations

6.5.3 *Two bin*

The two bin system is a very simple and cheap-to-administer version of a fixed order quantity system. Each item is held in two bins or packs in the stores. The first bin contains the main stock and the second bin contains the re-order level quantity and a travelling requisition. The storekeeper draws from the first bin until it is empty. He then removes the travelling requisition from the second bin and sends it to the stock control section for replenishment action. No paperwork, other than the travelling requisition is involved. The two bin system is ideal for controlling low value C category items such as fastenings. The quantity in the re-order bin can be based on planned demand as explained in **6.5.2**.

Some versions of the system operate with three bins. One of the bins is issued to the shops while two bins remain in stores.

6.5.4 *Base stock*

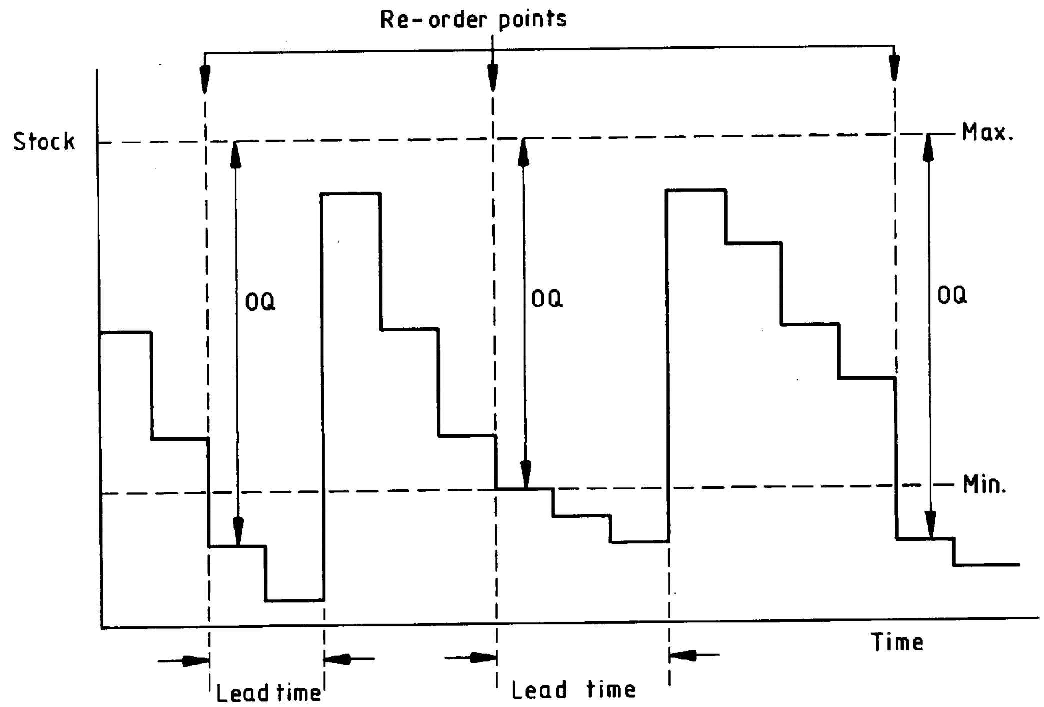
Production lines in which the processes are linked to one another in sequence may be fed from stocks, called base stocks, located at key points. A replenishment order is issued for the preceding process when consumption at the end of the line reduces the base stock at that point to the re-order level, i.e. that is a quantity sufficient to supply the production line during the time needed by the preceding process to replenish the stock. The action in turn triggers demands to top up base stocks up the line as stock is consumed.

The system avoids the instability that can occur if each stock is controlled in isolation and ensures that consumption is balanced by the demands of the line. It is a simple way of ensuring that production lines are supplied without having to hold too much stock. The system depends for success upon each stage in the production process being able to react swiftly and flexibly to demands made upon it and upon keeping lead times short. The kanban system described in **9.7** is a particular example of a base stock system.

6.5.5 *Min-max systems*

The aim of a min-max system is to set an upper limit to the amount of stock of an item that is allowed to be held. This is called the maximum stock level. Any item of stock that exceeds this level should be investigated. The maximum level is usually set as equal to the economic order quantity plus minimum stock. (See **4.5.3** for different methods of determining order quantity.)

The minimum stock level corresponds to the re-order level in a fixed order quantity system, i.e. the minimum quantity should be sufficient to meet forecast demand during the replenishment lead time. However, a min-max system differs from a fixed order quantity system by having a variable order quantity. When stock falls to or below the minimum level, an order is placed to bring the stock up to the maximum level. Minimum stock can include a safety stock. Further details of the system are shown in figure 11.



Key

OQ is the order quantity

Figure 11. Min-max re-order system

6.6 Advantages and disadvantages of stock control systems

6.6.1 ***Advantages***

The following advantages of stock control systems can be identified.

a) Stock control systems can be simple and cheap to administer and can be very effective when operated by an experienced stock controller with knowledge of the items he is responsible for.

b) The two bin version is suitable for controlling low cost items such as fasteners, where the value of the item would not justify the cost of using more sophisticated independent demand systems such as materials requirement planning (MRP).

c) Stock control systems are very suitable for controlling items that have independent demand, for example, finished goods in a warehouse.

d) They also work well when used as part of a hybrid replenishment system, the other part of which is a dependent push type technique. A notable example of a hybrid system is kanban/MRP. The kanban system pulls stock through the production process in the short term (hourly/daily), whilst MRP is used for planning the long term material supply (monthly plus).

Table 3 contains a summary of the applications for which stock control systems are suitable.

6.6.2 ***Disadvantages***

The following disadvantages of stock control systems can be identified.

a) Stock control systems, by themselves, are generally unsatisfactory in the manufacturing environment where a number of items have to be brought together at a particular time to produce a product or assembly.

b) There is no mechanism in a stock control system for determining priorities when one or more orders are in contention for the same item. Demands are normally processed in chronological order.

c) It is not possible with a stock control system to relate forward demand to available or required capacity.

Some of the deficiencies of stock control systems are shown in figures 12 and 13.

The characteristics of a stock item determine whether or not it is appropriate to use stock control. This is summarized in table 5.

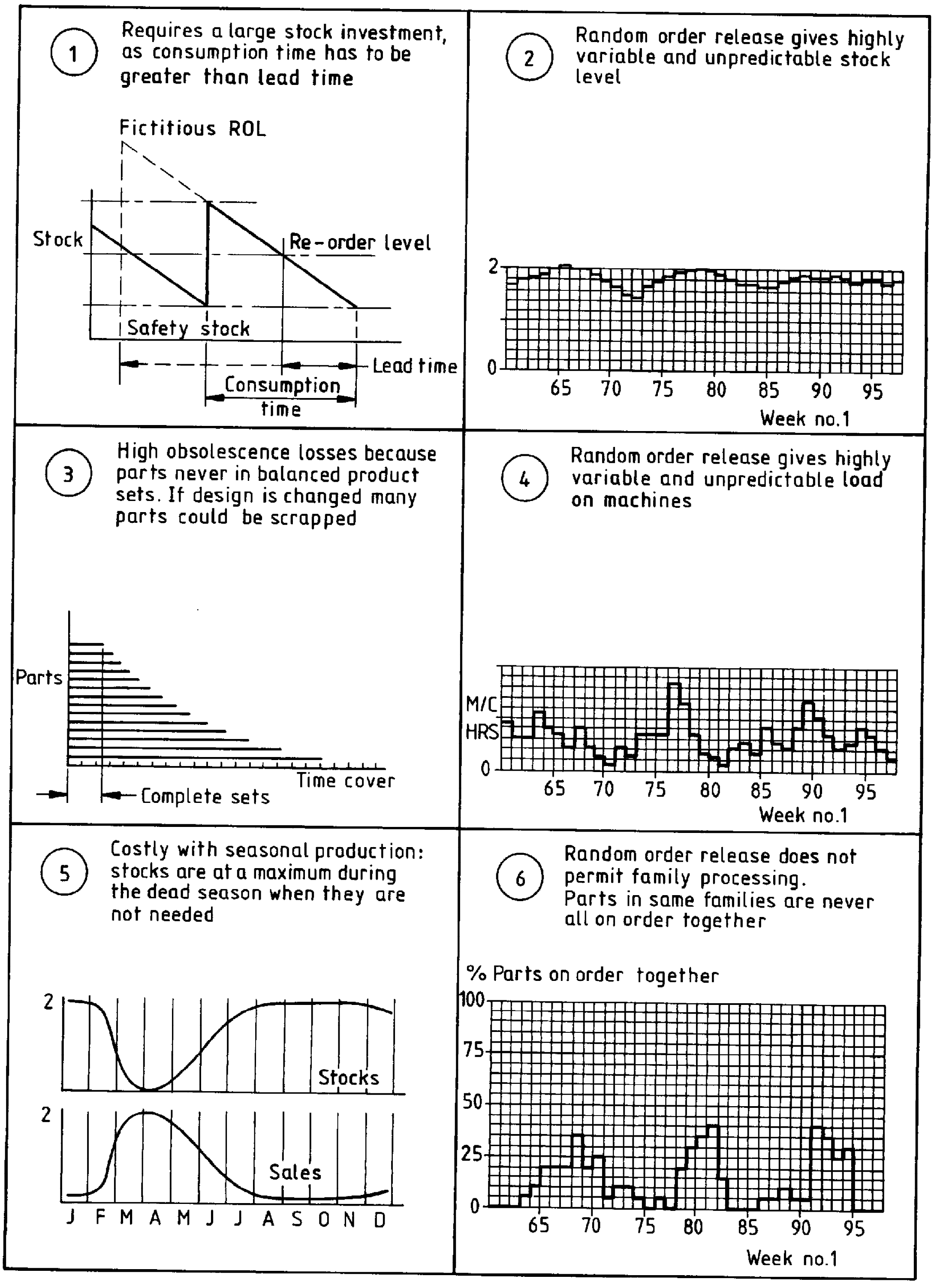


Figure 12. Deficiencies of stock control

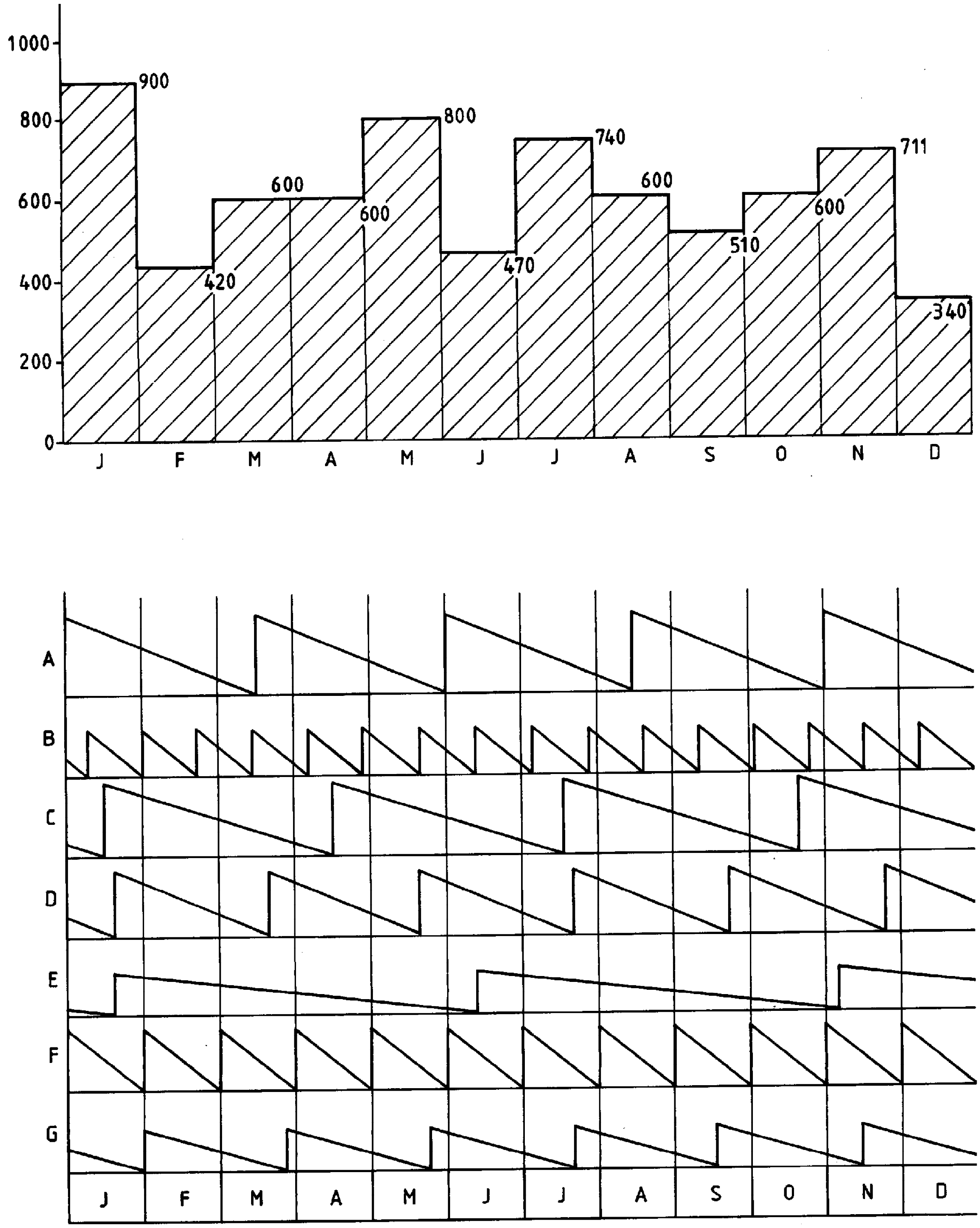


Figure 13. Variations in stocks due to multi-cycle ordering

Table 5. Uses of stock control systems

Criterion	Unsuitable for	Suitable for
Whether the source is made or bought	Made items: the stocks and load would be unpredictable	Bought items
Value of the stock	Class A (high value): high stocks would be needed	Class C (low value)
Whether parts are in sets	In sets: there would be a risk of obsolescence	Not in sets
Whether demand is seasonal	Seasonal: capital would be tied up in the dead season	Not seasonal
Whether the lead time is long or short	Long lead time: large order quantities would be required	Short lead time
Whether the stock is common or special	Special: there would be a risk of obsolescence	Common

7 Period batch control (PBC)

7.1 General

Period batch control (PBC) ordering systems are flow control, single cycle, push type ordering systems that can be used for jobbing, batch or mass production products.

7.2 The PBC method

The PBC method is applied as follows.

a) The year is divided into short equal periods.

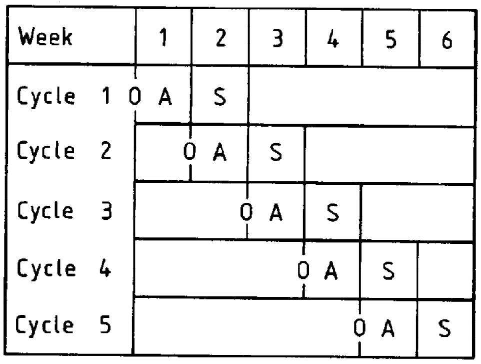
b) Short term sales and production programmes are fixed at the beginning of each period and are used to regulate sales and assembly.

c) The production programme is exploded to find the component and material requirements.

d) The component requirement is adjusted to allow for scrap, spares sales and component stock adjustment.

e) The net requirement is ordered to a standard ordering schedule.

PBC is merely an extension of flexible programming that allows additional period(s) for component manufacture and data processing. (See figure 14.)



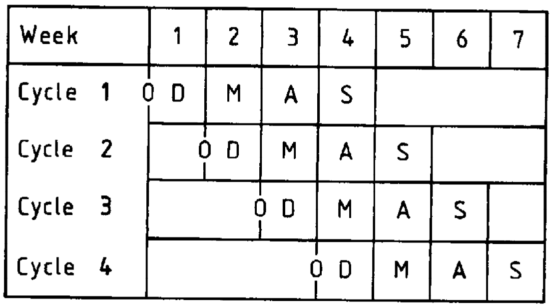
Key

O = Programme meeting

A = Assembly

S = Sales

a) Flexible programming



Key

D = Data processing

M = Make components

b) Period batch control

Figure 14. PBC as an extension of flexible programming

The principle of flexible programming is that, in each period, only the products that can be despatched to customers in the following period are assembled. PBC extends this principle down to the manufacture of the piece parts required for the following period's assembly programme.

7.3 The choice of period

All the products shown on a short term programme have to be assembled in one, or a small number of, periods. One period is always preferred if possible, but with complex products it may be necessary to allow separate consecutive periods for say: subassembly, main assembly, testing and packing, to cover the necessary throughput time.

All the made components required for each assembly period have to be completed in one period. The period chosen should therefore be related to the throughput time for completion of the whole range of components. The components required to assemble any engineering product comprise many simple parts with few operations and short operation times and a few complex parts with many operations and/or long operation times. The throughput time of batches of complex parts can generally be reduced if overlapping of operations is allowed, so that some parts are transferred to the next operation before all of the batch has passed through the previous operation. It is the throughput time of these complex parts that limits the choice of period.

The choice of period depends on the type of organization. For example, the assembly period for a product range might be four weeks using traditional process organization and one week using product organization, e.g. group technology (see **7.10**).

7.4 The short term programmes

At the beginning of each period there is a programme meeting at which the sales department produce a sales programme for the new cycle showing the quantities of different product types they hope to despatch to customers in the sales period for that cycle and the production department produce a production programme, showing the quantities they plan to assemble in the immediately preceding assembly period.

The production programme will attempt to meet the sales programme requirement and also to smooth production in order to compensate for random variations in market demand.

7.5 The standard ordering schedule

A series of major scheduling stages is planned, and one period is allotted for each one. For a simple product they might be as shown in figures 15 and 16, i.e. ordering, machining, assembly, sales.

For a more complex product the stages might comprise:

a) ordering;

b) make materials (foundry and forge);

c) component processing (machining and press work);

d) assembly;

e) test;

f) sales and packing.

An attempt should be made to plan the shortest possible schedule, as increasing the number of periods in the schedule increases stocks and work-in-progress and reduces flexibility to follow changes in market demand economically.

7.6 Ordering made parts

The quantities to be ordered are found by explosion of the period production programmes followed by adjustment. List orders are issued to each department, or group, every period.

7.7 Ordering materials and bought parts

There will generally be two methods of ordering (see figure 16).

a) Some parts are ordered using long term purchase contracts. Deliveries are called off against these contracts by sending call-off notes to suppliers each period showing the period requirements.

b) Other parts are ordered for stock, using other ordering methods.

Both the quantities on the call-off notes and the quantities to be issued each period from stores are found by explosion from the period production programmes.

7.8 Safety stocks

If necessary safety stocks can be used to insure against delays and rapid changes in demand. As far as possible they should be restricted to:

a) purchased common materials;

b) finished products.

Again it needs to be stated that it is more important to include in the system a method for the continuous revision of safety stock levels, than it is to have accurate methods for calculating the initial safety stock level.

7.9 Advantages and disadvantages

7.9.1 *Advantages*

The main advantage of PBC is that it eliminates all the disadvantages of stock control and of multi-cycle ordering. Using PBC it is possible to operate with:

a) lower stocks;

b) lower obsolescence losses;

c) efficient response to a seasonal demand;

d) small and predictable stock variations;

e) small and predictable load variations;

f) elimination of the demand magnification effect;

g) reduced set-up times (by using sequencing).

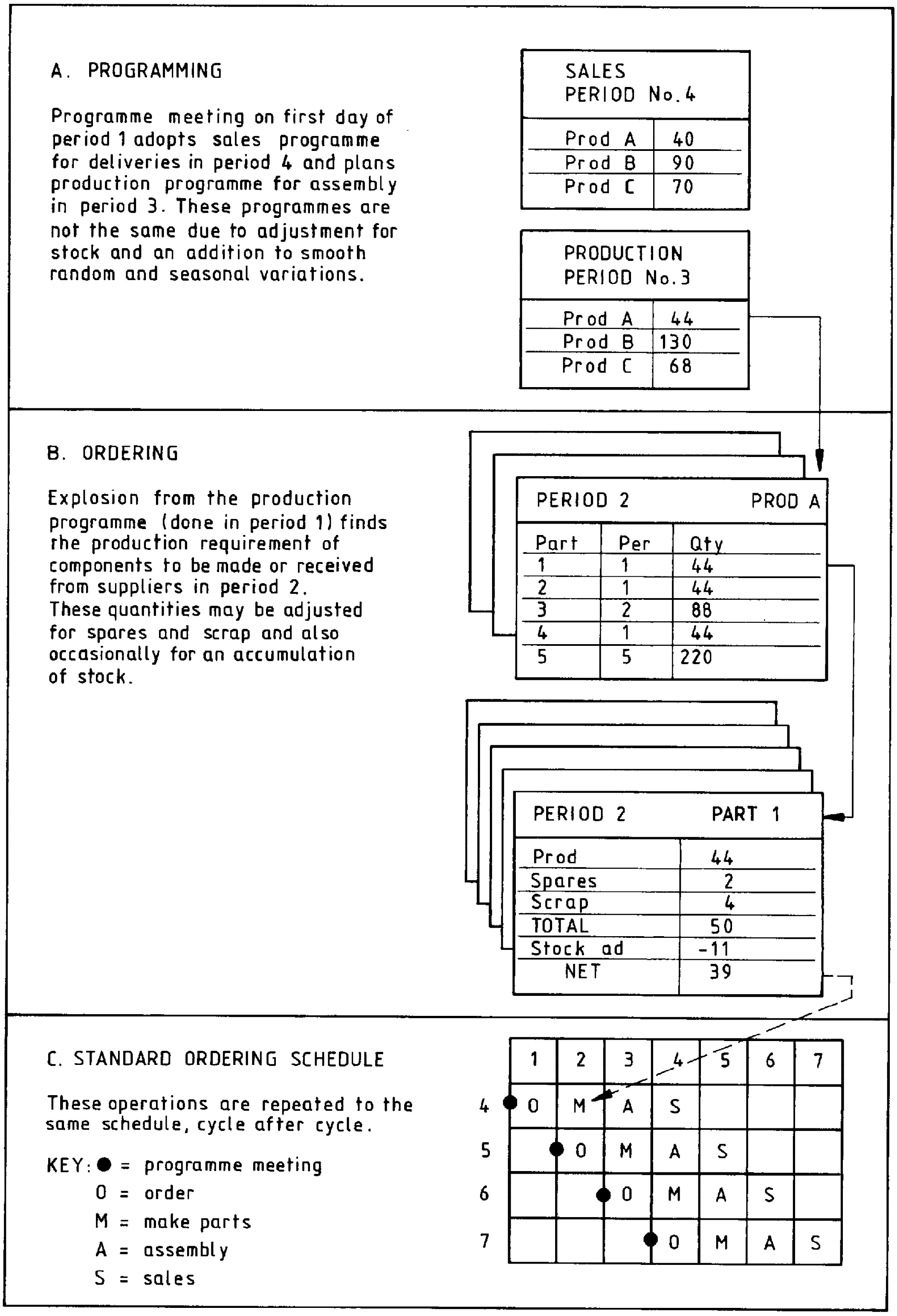
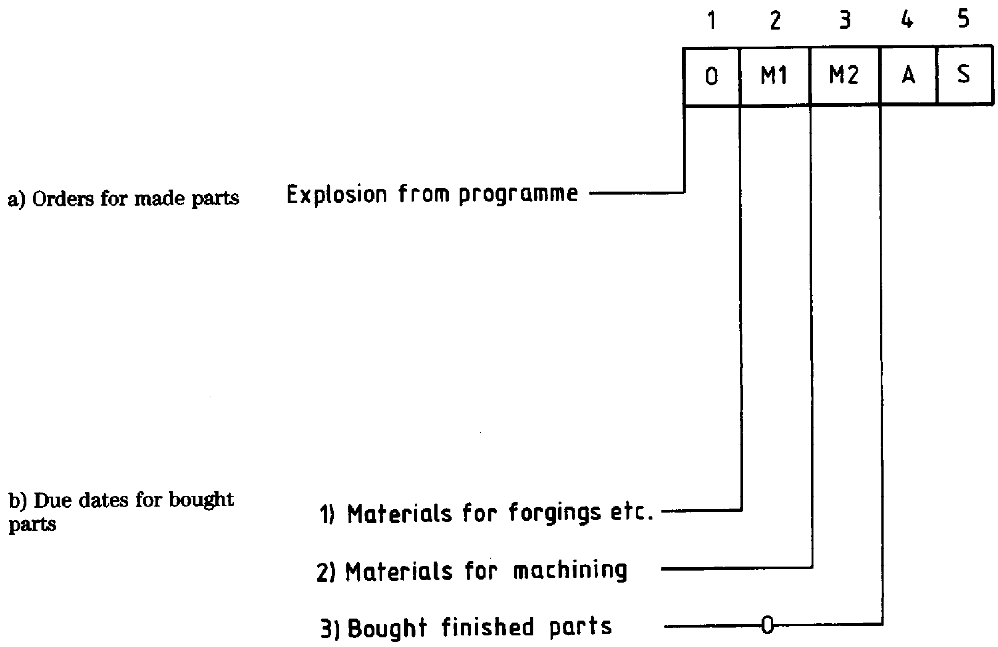


Figure 15. The PBC process



c) Buying methods

1) Call off against period programme. Allowing one period's notice for materials for machining (see b) 2) above), and two periods (see b) 3) above) notice for finished parts.

2) Scheduled delivery: long term programme exploded to find delivery schedule.

3) Stock control (see clause **6**)

Key

O = issue call-off notes

M1 = make materials

M2 = make parts

A = assembly

S = sales

Figure 16. Bought items and PBC

7.9.2 *Disadvantages*

The disadvantages of PBC are that it is necessary to:

a) reduce set-up times in order to avoid the erosion of capacity;

b) make major changes in purchasing policy;

c) equalize component lead times to the chosen period.

These problems can be and have been solved in practice.

7.10 Production types for which PBC is suitable

PBC has been used successfully to control production in the following types of industry:

a) mass production;

b) batch production;

c) small quantity jobbing production;

d) process industries (decorative laminates).

PBC is particularly suitable for use with group technology (GT). The simple material flow systems obtained with GT, make it possible to reduce throughput times and to use PBC with much shorter periods than was possible with traditional methods of organization based on process organization. Figure 17 shows how PBC is used with GT. The shop orders in this case are issued direct to the groups.

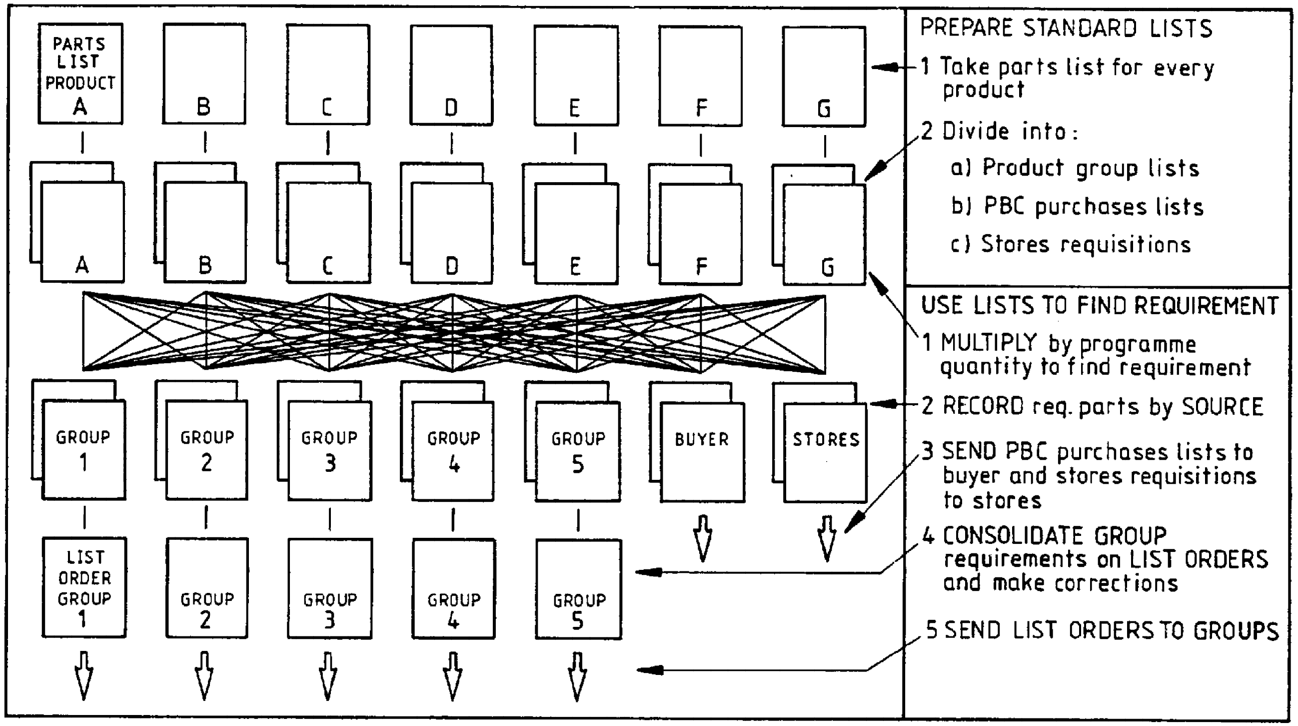


Figure 17. The PBC system

8 Material requirements planning (MRP)

8.1 General

Material requirements planning (MRP) is a flow control, multi-cycle, push ordering system that determines the parts required to satisfy a manufacturing programme.

MRP calculates the recommended requirement for parts net of stock, safety stock and parts on order. These requirements are time phased from the product need dates by the lead time and batched according to the ordering policy. MRP does these calculations at all levels of the build of a product and for a time horizon stretching out as far as the end of the master production schedule (MPS, see clause **5** of BS 5192 : Part 2 : 1993). It also recommends that existing purchase and works orders be expedited or de-expedited to their new need date.

Further details and examples of the MRP calculation may also be found in clause **5** of BS 5729 : Part 2 : 1981.

MRP works to precise dates rather than predetermined periods. In view of the considerable computation involved it is usual to operate a computer-based MRP system, particularly if the final product can be broken down into subassemblies, these subassemblies consist of further subassemblies and the components themselves are manufactured in-house.

8.2 MRP logic

The calculation of a requirements plan uses certain logical steps to determine its recommendations. The basic logic on which all MRP systems are based is as illustrated in figure 18. This logic becomes increasingly more complex if a company needs to take into account optional data (see **8.6**).

8.3 Essential data required for MRP

8.3.1 *Use of structures*

For every assembly on the production programme there will be a bill of materials showing how it is broken down into subassemblies, components and materials. Because a component may be used on more than one assembly the information will be held as a structure link record whereby the parent part number, the component part number and the quantities of the component part required to complete that link are defined.

The final assembly is usually defined as level 0, those assemblies and components from which it is manufactured directly are defined as level 1, and so on. A component or subassembly may occur at more than one level in a complex assembly or at two different levels for two finished products in the same production programme. Before MRP can be undertaken it is necessary to undertake a process whereby the lowest level of each part in any of the structures in the system is determined since the comparison of requirements with available stock and orders should not take place until the system has exploded all structures to that level.

8.3.2 *Data static with time*

The following static data are essential before MRP can be undertaken.

a) Part number: a unique identifier of the item.

b) Source: whether that item is purchased or manufactured (i.e. has components).

c) Low level code: the lowest level at which this part occurs in all of the bill of material structures in the company.

d) Component numbers: the components from which the item is made.

e) Component quantity per: the quantity of each component required to make one item.

f) Lead time: the time required to obtain the item.

g) Unit of measure: the unit in which the part is stocked.

h) Order policy: the method to be used when determining the quantity to be ordered at a time.

NOTE. Typical order policy options are as follows:

1) orders are handled manually outside the system;

2) orders are created on the basis of a one-for-one requirement;

3) orders are created by batching requirements either by period, or over a predetermined time span or by means of an economic order quantity algorithm (that needs to be specified), or by a re-order point control system.

8.3.3 *Dynamic data required for MRP*

The calculation is also dependent on two types of data which change with time.

a) *Supply.*

1) Stock balance: the onhand balance for the item at the time the calculation is made.

2) Supply on order: the quantity and date (or rate) of receipt of any orders already issued to the factory or supplier. Some systems will differentiate between firm orders which are documented and those which are committed but are not documented (i.e. proposed).

b) *Demands.*

1) Dependent demands: the requirements for the part in terms of the quantity and the due date (or rate) which come down from the MRP calculation of all items for which the part is a component.

2) Independent demand: the requirements for the part in terms of the quantity and the due data (or rate) from the MPS if this is a top level product. They may also come from forecast or actual orders for spares, development, etc., at any level of the bill of material.

3) Demand shortages: the quantity and date (or rate) of receipt of any orders already issued to the factory or supplier.

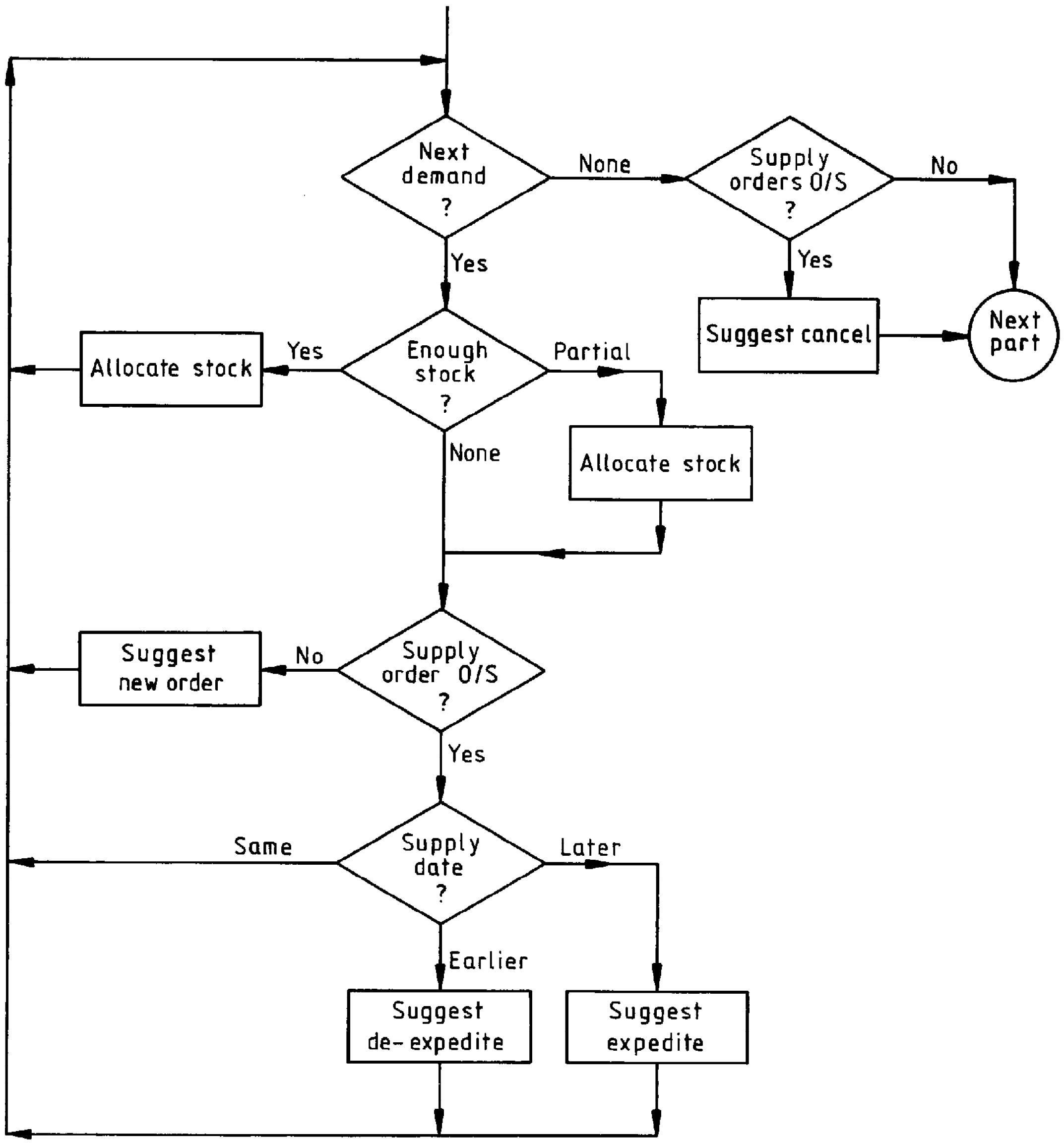


Figure 18. MRP logic flow diagram

8.4 Different modes of operation of MRP

The calculation of requirements in MRP may be driven by certain parameters and in certain modes.

In gross requirements planning the production programme is broken down without taking existing stock or works/purchasing orders into account. Gross requirements planning would tend to be used as part of a budgeting exercise, exploding a sales forecast to identify the forecast requirements. In net requirements planning existing stock and works/purchasing orders are taken into account. Net requirements planning can have two options when it is undertaken:

a) it can be regenerative when the planning reconsiders every part in the system, taking into account the new master schedule and existing orders;

b) it can be based on net change when only those items for which there has been a significant change since the system has last run are re-assessed.

There are different ways in which changes can be identified for a future net change requirements planning run; the usual method is to set a trigger when the requirement for the finished product is altered (e.g. a new contract is received), the structure is amended (e.g. a washer is added to a bolt), the lead time for a purchased item is amended or there has been a stock write-off. The triggers are cleared as part of the net requirements planning process.

8.5 Stages in an MRP run

A net MRP run consists of the following stages.

a) At the highest level the requirements for each part number are gathered in ascending due date sequence unless there are requirements for that part at a lower level (as explained in **8.3.1**).

b) The requirements are netted first against the physical stock and then any remaining requirements are compared with the outstanding orders in ascending due date sequence. If orders are out of phase with requirements the system may recommend rescheduling and will assume that this action will be taken.

c) For requirements that cannot be satisfied from physical stock and orders, the system will then recommend orders to be placed dependent on the ordering method set (as explained in **8.3.2**) and taking scrap allowance into account where specified. The order is given a due date in line with the earliest requirement that it is to satisfy. For a manufactured item this order is now a requirement to be exploded. Again the system assumes that these orders will be raised.

d) The works orders are exploded into dated requirements for components based on the structure link record (which gives the component part and the quantity required) plus the lead time.

e) The process is then repeated for the next lower level, the gathering operation taking requirements from the higher levels as well as the present level unless a specific part still exists at a lower level.

f) When the process has been completed for every level, the system will generate a listing of the action to be taken, i.e. orders to be raised, amended or cancelled.

With some systems the user will be presented with the appropriate template so that the required action can be confirmed into the system.

For gross requirements planning the same procedure is followed, except that the netting stage is omitted.

8.6 Optional data required for MRP

From the stages in an MRP run (see **8.5**) it will be appreciated that data additional to the data described in **8.3** may be required by a company.

Some of the features that companies may need are as follows.

a) *Scrap allowance*. The amount of scrap to be allowed for when making a manufactured, or using a bought-in, part (see figure 19).

b) *Safety stock*. The amount of stock that should be held at all times.

c) *Safety lead time*. The extra lead time that should be allowed for before the need date of all demands.

d) *Shelf life*. The time for which this item may be stored before it has to be scrapped.

e) *Byproduct data*. The quantity of a new part number produced with each item as a result of processing.

f) *Process yield factor*. The proportion of usable components resulting from the method of processing (see figure 19).

g) *Component delivery-to offset*. The number of days after the issue of the job when this component is needed and the operation delivery address.

h) *Component effectivity dates*. The date the component enters and leaves the design.

8.7 Good MRP practice

There have been a large number of relative failures to use MRP effectively. An examination of the key success features behind the successful users reveals certain common features:

a) an educated and committed workforce, trained to use the software and hardware in the appropriate way for their business;

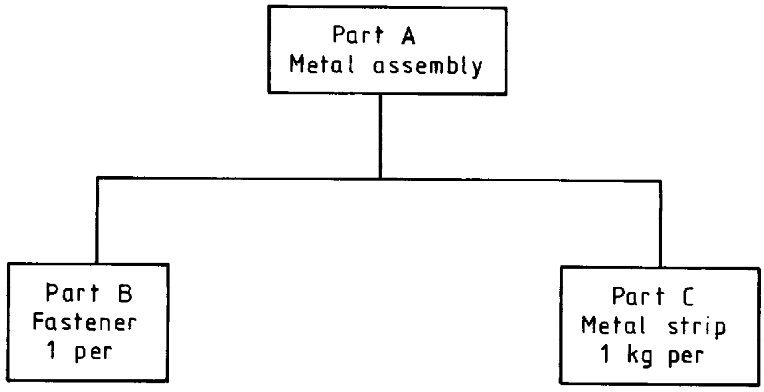
b) accurate data:

stock balances > 95 % correct

bill of material > 99 % correct

routeings > 99 % correct

orders (purchase, works and customer) correct;



Part A: Scrap allowance	= 5 % (out of tolerance)
Part C: Yield field	= 75 % (circular blank)

Calculation of requirements for 100 of part A

Part B: Number of fasteners	$= 100 \times 1.05 = 105$
Part C: Mass of metal strips	$= \frac{100 \times 1.05}{0.75} = 140$ kg

Figure 19. MRP scrap and yield calculation

c) very few past-due dates and these readjusted to real dates promptly;

d) recognition of the importance of schedule adherence at all levels of the organization;

e) a stable, viable master schedule that has been checked against all major resources and against the company plan;

f) regular reviews of all parameters and commitment to reduce those that hide waste and delay (lead time, scrap %, yield %, safety stocks, safety time, set-up times, large batch sizes, etc.).

8.8 Advantages and disadvantages of MRP

8.8.1 *Advantagges*

MRP has the following advantages.

a) It uses the real logic of production (often referred to as the informal system) to plan the following requirements:

- what is to be made and when it should be made;
- what is needed to make it and how long the process will take;
- what materials are in stock or on order;
- what has to be ordered and when it is needed.

b) Dependent demand is calculated automatically.

c) Need dates are time phased by lead time.

d) Requirements are calculated net of stock and orders on hand.

e) It takes into account expected scrap and yield rates.

f) It permits representation of engineering, costing and selling as well as manufacturing bills of material, within one system.

g) It may be run frequently on a net change basis to calculate new need date.

h) The computer generates action reports on screen or printout at user request. Many users can therefore work from the same data.

i) It takes into account engineering change and process change.

j) It is a people system, where the computer does the complex calculating and recording and then recommends actions, leaving people to decide on the correct action to minimize problems.

k) MRP systems can be used in many ways. The parameters can be adjusted to drive a PBC system, can drive a complex multi-cycle design-to-order system, or a high volume, flow manufacturing company.

8.8.2 *Disadvantages*

MRP has the following disadvantages.

a) It requires accurate data (as do all other systems).

b) The standard planning assumption is of infinite capacity. The resulting shop floor (and purchasing) plan should therefore be checked against actual capacity. Action should be taken to relieve overloads. It should be driven by master production scheduling (MPS), managed to remove major overloads.

c) Because of its flexibility, people have to be educated to understand what MRP can and cannot do, how to use the system and how to set policies and parameters to minimize stock and throughput time.

d) It requires feedback of information and replanning to maintain credibility of the dates and quantities.

e) The precision of computer calculation may mislead people into inflexible use of the software. Any long lead times imply forecasts which have to be treated as changeable.

9 Just-in-time (JIT)

9.1 Evolution and concepts

Just-in-time (JIT) had its origins in Japan during the 1970's when a form of JIT known as the kanban system was introduced in the automotive industry.

By making the container quantities small and by frequent replenishing, as often as 10 times a day in some cases, Japanese manufacturers were able to keep work-in-progress stocks very low. This in essence is the logic of JIT. It aims to achieve very low or near zero stocks by ensuring that only those parts and materials are supplied which are required for immediate production.

Kanban is on the surface a simple pull system of scheduling, but the implications of JIT extend far beyond this system and embrace almost all facets of manufacturing operations. JIT is a concept, not a system, and it requires a change in attitude towards the problems that beset manufacturing operations. Traditionally, stocks have been regarded as buffers between intermediate stages of manufacture intended to reduce the risk of disruption arising from such hazards as poor quality, delays by suppliers and machine breakdowns. Instead of accepting these hazards as inevitable, the JIT approach is to seek ways to eliminate them.

The level of stock is also a function of batch size which in turn is determined by the time and cost to set up machines and place orders. Stock reduction is therefore dependent on finding quicker, more simple and less costly ways of setting up machines and placing orders.

JIT is dependent on the basic elements of quality, suppliers, technology and people.

9.2 Quality

Pursuit of quality and the elimination of defects and waste requires the involvement of the total workforce, not just those responsible for the quality control function. The philosophy of total quality management (TQM) begins with the design in order to eliminate the features that create quality problems either during manufacture or service. It continues through every stage of manufacture with each worker having responsibility for the quality of his work. Further details of TQM may be found in BS 7850 : Parts 1 and 2.

9.3 Suppliers

With JIT, suppliers become an extension of the plant's resources. The same insistence that applies to internal operations concerning quality standards, zero defects and on-time delivery of the right quantity applies to suppliers. In return, the adversarial attitude commonly adopted towards suppliers has to be abandoned in favour of close cooperation and sharing information about production plans and requirements.

9.4 Technology

The ability to reduce batch sizes depends upon improvements in manufacturing technology that cut set-up times and costs whilst also maintaining consistent quality standards. Improvements can be comparatively simple like development of quick change tooling for existing machine tools, or they may result from the introduction of numerically controlled machines, or they can involve extremely complex developments such as fully automated flexible manufacturing systems.

9.5 People

JIT is a very demanding concept. It requires dedication and commitment from all those involved in order both to surmount difficulties and to contribute towards a process of continuous improvement. This applies not only to those engaged directly in the manufacturing process but also to all those in ancilliary services such as maintenance. In a JIT environment, schemes such as planned maintenance are vitally important as a means of minimizing breakdowns.

9.6 Applications and benefits

Originally developed for mass production industries like automotive manufacture, JIT is also applicable to quite small manufacturing plants. JIT principles apply in any situation where opportunities to reduce inventory and cut batch sizes can be identified.

Implementation of JIT is a gradual process which generally involves a number of parallel activities: education of the workforce and suppliers; improvements in manufacturing technology; changes to production systems. Operations which have the greatest potential for improvement should be tackled first and the process continued until a point is reached where the returns cease to be significant. JIT is not therefore a finite process; rather it is a process of continuous improvement of manufacturing operations aimed at eliminating all activities that do not add value to the product.

The scheduling part of JIT, of which the kanban system is an example, is simple and may be entirely manual. However, such a system usually forms part of a more complex system for long range production planning and provisioning such as material requirements planning (MRP) or manufacturing resource planning (MRP II).

JIT has many benefits, the principal one being reduction of inventory. Other significant benefits are improved quality, fewer defects, elimination of waste, shorter manufacturing lead time, lower costs and a more flexible production programme more closely attuned to market needs.

9.7 The kanban system

9.7.1 ***Background***

The kanban system is a technique for controlling the replenishement of goods sold or moved out of a manufacturing area. It originated from observations of how supermarkets replace goods that are sold from bulk. The development of the system is described by Shigeo Shingo in *Study of Toyota production system from an industrial engineering view point* [2]. It is a shop floor control system.

The word kanban is Japanese for billboard or sign. Typically it is a card that may be placed in a plastic wallet. It identifies the part, its batch size, where the components are obtained from, what process is carried out and where the finished item should be placed. It may also be in the form of a container, a space on a bench or the floor (kanban square) with the above information written on it.

9.7.2 ***The basic method***

The following steps are taken to set up a kanban system:

a) selection of a suitable series of operations in the manufacture of one or more items;

b) master production scheduling (MPS) of these items to smooth overall demand;

c) decision on the quantity of items in a unit load and the number of unit loads at each process stage;

d) designation of material store and finished work areas for each process stage;

e) preparation of kanbans for in-process and inter-process (also supply, if appropriate) control;

f) preparation for and implementation of the system;

g) continuous improvement of the system in use.

9.7.3 ***Selection of processes and items***

Initially it is best to choose a series of processes that do not have widely varying process times or quality problems and that are physically close to one another. An item or items (family) that pass through these processes are then selected so that they do not overload the process capacities.

9.7.4 ***MPS of items***

The items selected have to be master scheduled. The kanban system has no capacity planning ability and the MPS should therefore smooth the overall demand for the family. The capacity loaded should be just below the demonstrated capacity.

9.7.5 ***Unit load sizing and number***

The number of items in a unit load should be the smallest number that can be produced in a batch without causing undue set-up scrap or lost time. If there is more than one item in the family then it may be necessary to have two or more unit loads in between each process. The number is dependent on the number in the family, the process reliability, demand pattern and set-up times. In the Japanese automotive industry, unit loads were planned on the basis that 10 unit loads would provide one day's demand.

9.7.6 ***Storage areas***

Each process stage normally has an incoming area where material is held in containers ready for processing. It also has an outgoing area where the finished work from the process is placed after processing. Each area should be large enough to hold all the unit loads of each item going through that process (see figure 20).

9.7.7 ***Kanban preparation***

In-process kanbans are printed for each process with the information indicated in **9.7.1** and placed with each unit load of parts for that process in the outgoing area (see figure 21).

Inter-process kanbans are prepared in a similar manner (but without process data) and placed with each unit load of parts for the process in the incoming area. In closely coupled areas the incoming of one machine may be the same as the outgoing of the previous. In this case no inter-process kanban is needed.

Supply kanbans are similar except that they will circulate back to the vendor and more unit loads may be necessary to buffer against supply frequency and reliability. They should be supported by a supply contract agreed with the vendor.

9.7.8 ***Preparation and implementation***

The introduction of a kanban system should be carefully planned because the technique is very different to the normal European dispatch list and traveller documents that inform the operator what to do and how to identify the goods respectively. Kanbans circulate through specific locations and are not replaced with each batch (see figure 20). If a process has several kanbans on the schedule board then the operator should take the required parts on a first in, first out basis (batching up destroys the pull signal sequence). If no kanbans are present the operator should do nothing. Thorough education and training are essential for operators and supervisors. If vendors are to be included then this aspect is even more important.

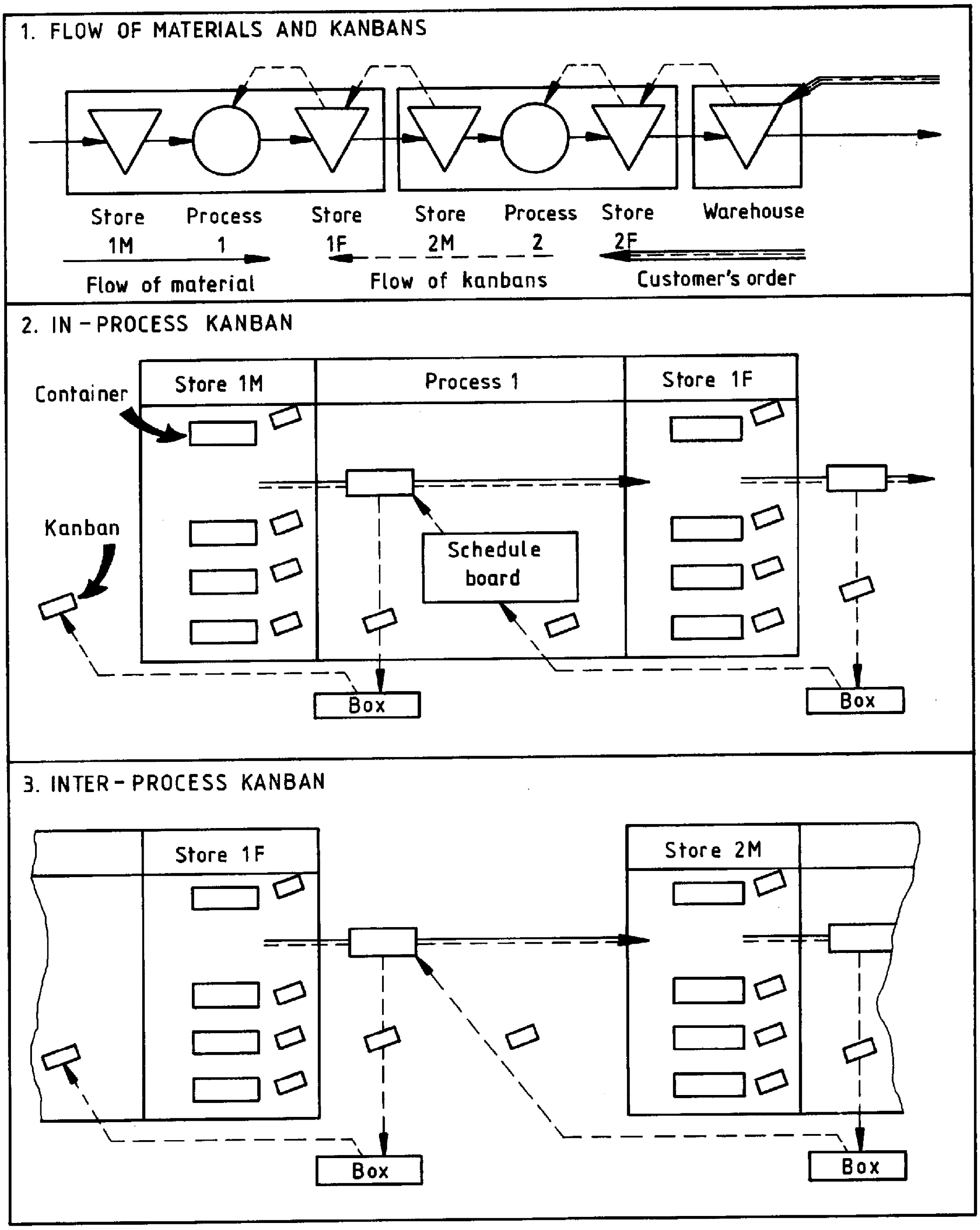


Figure 20. The kanban system

In-process kanban

IN-PROCESS

M/C : W38
Part No : 720 -6592 Lay Shaft
Dwg No : JE457-6 Process Ref: A28s
Container : XC3/12 Qty : 50
Place at Location : 038/1
Material : S567-XC3 Shaft Blank From : 138/3
Card No : 1 of 3

Inter-process kanban

INTER-PROCESS

Part No : S567-XC3 Shaft Blank
Container : XC3/12 Qty : 50

From Location : 025/7 M/C W25
To Location : 138/3 M/C W38
Card No : 3 of 5

Supply kanban

SUPPLY

Supplier : Production unit 1, Sheffield
Part No : HSS-3-T5 25 mm diam × 300 mm Bar
Container : TZ18 Qty : 50

Deliver to : Production unit 9, Barnsley
Location : I17 M/C W17
Card No : 6 of 14

Figure 21. Kanban types

9.7.9 ***Continuous improvement***

The philosophy of continuous improvement is central to JIT and to get a kanban system working is not enough. All staff involved, particularly the operators and supervisors, should strive to make the system perform better.

Examples of the many improvement techniques that have been identified are as follows:

- layout to encourage good communication (U-shaped cells);
- design for manufacture to make production simple and to encourage group technology families;
- set-up reduction;
- quality at source (total quality management);
- preventive maintenance;
- statistical process control;
- supplier integration;
- multi-skilled operators;
- balanced work-content;
- visible sign boards, etc.

9.7.10 ***Advantages***

The main advantages of JTI are as follows:

a) it can achieve very high flow rates (stock turns);

b) it is a manual system and therefore cheap to operate;

c) it is controlled by the supervisor and is flexible;

d) it is visible to all employees and encourages involvement and problem solving.

9.7.11 ***Disadvantages***

The main disadvantages of JIT are as follows.

a) Substantial set-up reduction and process improvement programmes may be necessary for it to work well.

b) It does not plan capacity and therefore will only work if there is a steady master schedule family demand rate. It is easier to implement if the volume is high and continuous.

c) It requires a new style of supervisor/operator behaviour and a high level of discipline.

d) No material tracking is provided in the system.

e) If a supplier is to be included in the kanban system, then a high degree of education and co-operation will be required to avoid stoppages.

List of references (see clause 2)

Normative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 3138 : 1992	*Glossary of terms used in management services*
BS 5191 : 1975	*Glossary of production planning and control terms*
BS 5192 :	*Guide to production control*
BS 5192 : Part 1 : 1993	*Introduction*

Informative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 5192 :	*Guide to production control*
BS 5192 : Part 2 : 1993	*Production programming*
BS 5192 : Part 4 : 1993	*Dispatching (shop-floor control)*
BS 5729 :	*Guide to stock control*
BS 5729 : Part 2 : 1981	*Demand assessment*
BS 5729 : Part 3 : 1983	*Replenishment of stock*
BS 7850 :	*Total quality management*
BS 7850 : Part 1 : 1992	*Guide to management principles*
BS 7850 : Part 2 : 1992	*Guide to quality improvement methods*

Other references

[1] FORRESTER, J.W. *Industrial dyamics*, Cambridge, MA: MIT Press, 1961.

[2] SHINGO, Shigeo. *Study of Toyota production system from an industrial engineering view point.* Japan Management Association, 1981.

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