CEMAST

A brief description of the fundamental features of the project

BBC

CEMAST

Control of
Engineering
Material, its
Acquisition,
Storage and
Transport

A brief description of the fundamental features of the project

BRITISH BROADCASTING CORPORATION

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A photograph taken at the Press Conference on 28 June at which news of the CEMAST project was released. Left to right are W. E. C. Varley (Chief Engineer, Transmitters at that time), J. Redmond (Director of Engineering), D. M. Preston (Head of Computer Planning) and P. D. Hall (a Director of International Computers Limited)

PREFACE

At a press conference on 28 June 1968, Director of Engineering released news of the BBC's *CEMAST* project and of the financial savings achieved by the pilot scheme applied in the Valve Stores. The conference aroused interest both inside and outside the Corporation, and this booklet has been issued to give a simple account of the fundamental features of the project.

The booklet was prepared by Technical Publications Section with help from the CEMAST team in the BBC Management Services Group.

Readers wanting more details of the system described in Chapter 3 are referred to an article, 'Data Control and Forecasting at the BBC', (*Data Processing*, July/August 1968) by S. Kandiah. Copies are obtainable from Technical Publications Section.

The photograph on the cover shows the computer room at the Langham.

1

PRINCIPLES OF INVENTORY CONTROL

Introduction

A requirement for efficient management is the ability to assess a number of factors some of which may suggest conflicting courses of action and to decide between these after giving each factor its correct weight. One management activity to which this decision-making process applies is the control of material resources such as stocks and inventories.

Inventory differs from stock in that it includes raw materials, materials under treatment, components, sub-assemblies, finished goods, tools and jigs and other items, all of which must be bought and stored. The capital tied up in purchase and storage costs may amount to a significant proportion of the total investment of an organisation.

Effective inventory management can thus be important. The Central Statistical Office of the Board of Trade gives the current value of the national inventory as £12,500,000,000. If more efficient inventory control could enable this figure to be reduced by 10 per cent – and the indications are that it could – large sums could be released for more productive use.

The problem is that for a stores department to provide a high standard of service (i.e. to supply most required items from stock on demand) considerable reserves must be held in the form of inventory and inventory-carrying costs are thus high. In fact, as shown in Fig. 1.1, a 100 per cent standard of service requires an infinite inventory-carrying cost. Reductions in the cost of inven-

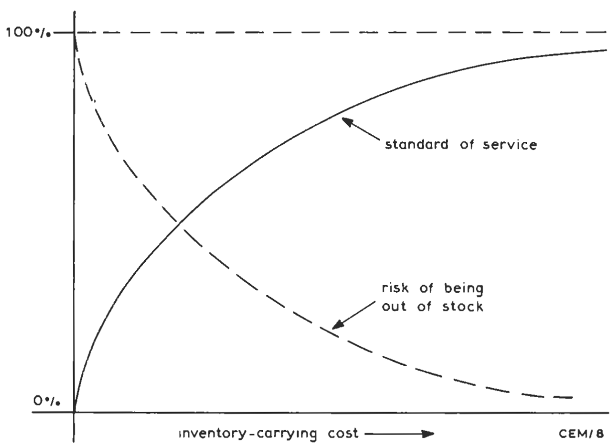

Fig. 1.1 Dependence of standard of service on inventory-carrying cost

tory can be achieved only by reducing the standard of service (i.e. by increasing the risk of being out of stock).

There are many systems which control inventory to some degree. Each one aims at providing an acceptable standard of service with minimal inventory costs. Ideally a system should give accurate, relevant, and timely information to enable management:

(a) to assess the consequences of policy decisions affecting the standard of service, before carrying them out,
(b) to relinquish rather arbitrary (and often unsound) methods of forward planning in favour of a high-speed assessment of all factors involved, and
(c) to monitor the operation of the system to confirm that policy decisions are being carried out satisfactorily.

Inventory Control

The information required by management for efficient control of inventory is a continuous flow on two parameters. These are (a) the *re-order level* (i.e. the inventory level at which replenishments must be ordered), and (b) the *re-order quantity*. In general the problem is to relate and adjust these in such a way that the accepted standard of service is maintained at minimum cost.

(*a*) *Re-order Level*

One way of deciding when to re-order is to set a level depending on the rate of withdrawal for each item and to note when the inventory has fallen to this point. In determining the re-order level, two main costs must be considered: (1) the cost of carrying more inventory than is needed to meet the demand, and (2) the cost of alternative action when items required immediately are not available.

(*b*) *Re-order Quantity*

If after examining the re-order level, a decision to re-order is indicated, it is then necessary to determine the re-order quantity. In calculating this the cost of initiating an order is an important factor. This cost may not be obvious, and may call for some analysis to establish it.

Re-order level, rate of withdrawal and re-order quantity are illustrated in Fig. 1.2 for an ideal system in which all these quantities are constant. The *re-order time* marked on this diagram is the time taken for goods to be delivered after they have been ordered; this too is assumed constant. In practice such ideal conditions are never realised.

The values of re-order level and re-order quantity together determine the physical inventory level. If they are too high the result is over-stocking; if they are too low, the standard of service is reduced, because items are often out-of-stock. This is illustrated in Fig. 1.3 in which re-order level, re-order quantity, rate of withdrawal and re-order time are shown as varying quantities. The shaded areas indicate short periods of over-stocking and out-of-stock.

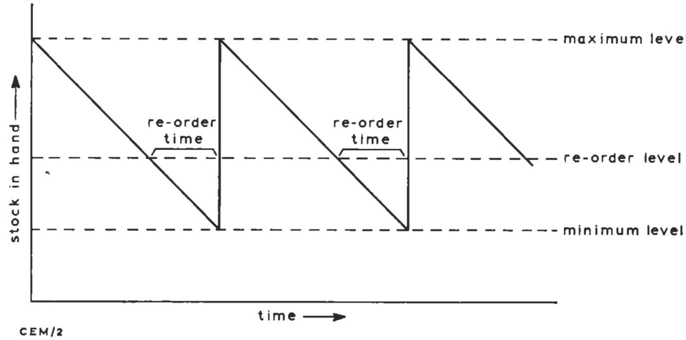

Fig. 1.2 Variations of stock level for constant demand and re-order time

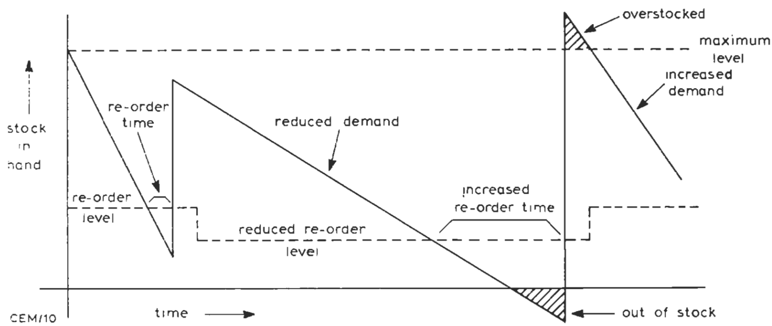

Fig. 1.3 Typical variation of stock level for varying demand and re-order time

Over-stocking

Over-stocking is expensive in terms both of the capital tied up in inventory and of the overheads incurred in storage. These overheads include the cost of buildings, storage racks, heating, lighting and ventilation, and also labour. In addition, breakage in Stores and depreciation costs must be considered. Items stored for a long period can become obsolete and require replacement without ever going into service. Some expensive items such as transmitting valves carry a guarantee for a set period; as the guarantee is intended to be a financial safeguard against operational failure, it is expensive to let it run out in Stores. Again, some items supplied under guarantee, e.g. television camera tubes, need regular maintenance while held in Stores. Certain other items deteriorate in storage; dry batteries are wasted unless used before their shelf life has expired. All these costs can be reduced simply by reducing the size of the inventory.

Under-stocking

On the other hand, it can be expensive to be out of stock. For example, a transmitting valve may be required urgently, to avert a possible breakdown of service. If it is not available in the store, cost is incurred in finding an alternative source of supply, and in any special arrangements which may have to be made to transport the valve to the transmitting station, which could be at a remote site.

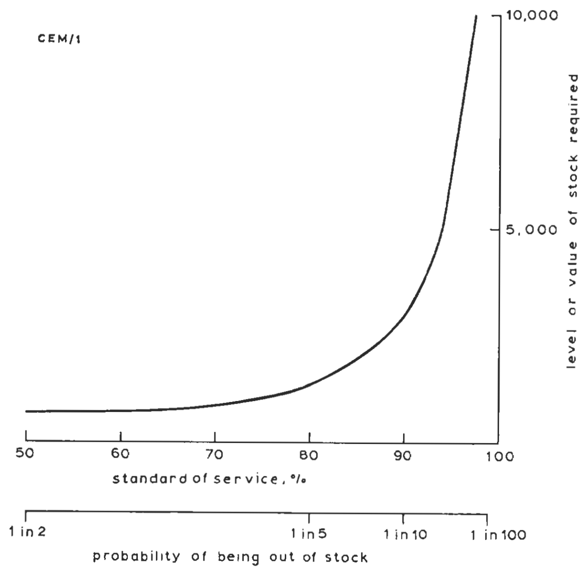

Fig. 1.4 Dependence of standard of service on size and cost of stock

If, however, a calculated and reasonable risk of being out of stock for a period can be accepted, a considerable reduction in cost can be achieved by holding a smaller inventory. This is illustrated in Fig. 1.4, in which the probability of being out-of-stock is plotted against the level of stock. The curve shows that to reduce the risk of being out-of-stock to below say 1 in 5 (80 per cent standard of service) or at most 1 in 10 (90 per cent standard of service) requires a disproportionate increase of inventory and hence of inventory-carrying cost.

Cost of Ordering

To appreciate the significance of the cost of placing an order, we shall consider a typical ordering procedure in a large organisation. This is represented diagrammatically and in simplified form in Fig. 1.5.

The order is initiated by a requisition to the buying department, where the buyer negotiates or confirms the details, such as price and delivery period, before placing the order with the supplier. Once placed, the order is progressed until delivery, when the storeman checks the accuracy of delivery, and advises the accounts department, which on receipt of the invoice arranges for payment to be made. In practice buying procedure can be more complicated than suggested, but it always involves costly effort of some kind in several departments of the organisation in addition to the cost of the goods themselves. The cost of this effort and of the materials involved in placing an order is called the *cost of ordering.*

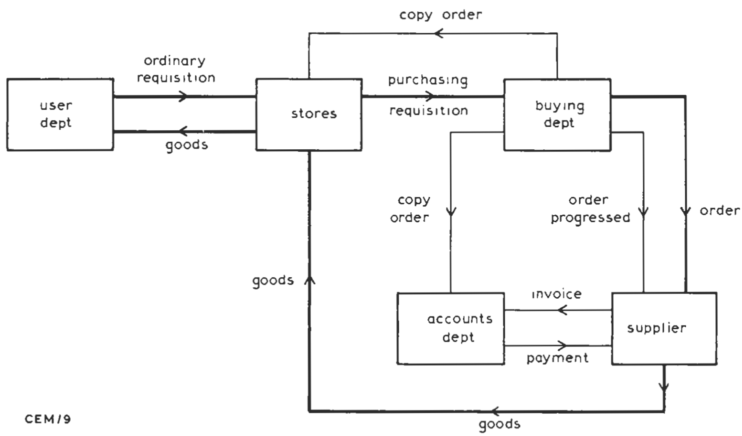

Fig. 1.5 Simplified ordering procedure in a large organisation

Optimum Ordering Interval

To maintain a stock of items it is necessary to re-order from time to time. If re-ordering is done only once a year (as may be permissible provided a large enough stock is held) the re-order cost is likely to be small, but if re-ordering is done very frequently (because only a small stock is held) the re-order costs may be appreciable. Clearly the re-order costs become greater as the stock is reduced; this is shown by curve BC in Fig. 1.6. Thus, a small stock entails small storage costs but high re-order costs, whereas a large stock has high storage costs and low re-order costs. The combined cost of storage and re-ordering is high at both extremes, but at some intermediate level of stock, where the two curves of Fig. 1.6 intersect, the total cost is a minimum. The point of intersection indicates the most economic stock level and re-order frequency; these can be calculated and are two of the factors taken into account in a comprehensive inventory-control system.

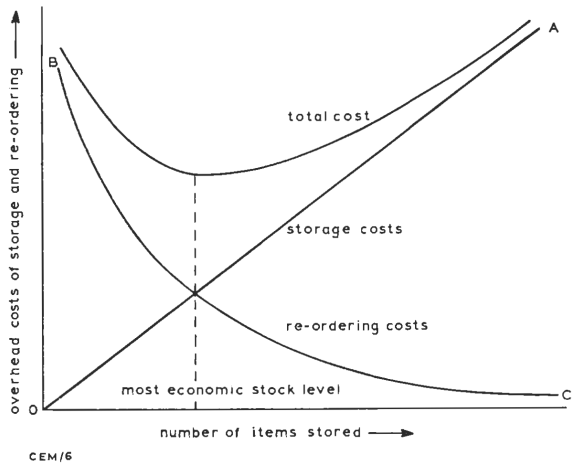

Fig. 1.6 Variation of storage and re-order costs with number of items stored

Economic Re-order Quantity

Consideration should also be given to the advantages of re-ordering in quantities which give the most favourable terms (usually reflecting the supplier's preferences in handling). This quantity is called the *minimum order quantity*. When the re-order quantity takes into account the minimum-order quantity and the cost of ordering it is called the *economic re-order quantity*.

Control System

An inventory control system thus deals primarily with the re-order level and economic re-order quantity for each item*. By monitoring, and so producing reports when management action is required, it permits the formulation of effective policies and ensures their operation in the most efficient manner.

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* The optimum re-order level and quantity may sometimes be zero. This can apply to slow-moving items, which are detected by the system as a prelude to their possible elimination.

2

APPROACH TO INVENTORY CONTROL IN ENGINEERING DIVISION

The CEMAST Project

The letters *CEMAST* stand for the Control of Engineering Material, its Acquisition, Storage and Transport, and provide the code name for a project launched in 1966 by the Engineering Automation Development Committee (E.A.D.C.). This project is being carried out by specialist members of Management Services Group with the help of some seconded staff from Engineering Division.

The aim of the project is to design a system which will ensure that engineers receive the materials they need, with minimum local action at minimum cost and with minimum delay consistent with an acceptable standard of service. At the same time the system is required to give proper accounting and auditing control.

We have seen that effective inventory control requires a correlation between rate of withdrawal and re-order quantity, conditioned by cost of ordering and minimum order size, and capital, storage and depreciation costs. In addition it is necessary to forecast future demand and this can be done by analysing past demand and in particular identifying seasonal or cyclic variations. A further factor to be considered is the required standard of service, which depends on the nature of the stored item as explained in Chapter 1. When all these factors are taken into account the calculations become so complicated that they are difficult to make quickly enough without using a computer. A practical example of a computer-aided system is described in Chapter 3.

Implementation

The aims of CEMAST are being implemented in four stages.

The first stage was to classify engineering materials to distinguish between those needed immediately, those needed within say four hours, those needed within one day, and so on. This priority classification permits the most suitable location (e.g. local stores or base stores) to be decided. For example, a camera tube or transmitting valve used in operational equipment should carry high priority, because when it fails a replacement is wanted within minutes. On the other hand, a transistor in an oscilloscope or other test equipment may have low priority, because it is satisfactory to produce a replacement in a few days.

The second stage was the development of a single coding system applicable to all items in the engineering inventory. Such a system not only is desirable for use with a computer, but also has advantages in itself. For example, it highlights equivalent items which are stocked under different trade names or type numbers and possibly by more than one store. Giving equivalent items the same code identification stimulates reduction in variety and encourages standardisation. Substantial reductions in the capital value of inventory can be achieved simply by the use of a good coding system.

An example of this is provided by Zener diodes. A particular diode rated at 6·8 volts (5 per cent tolerance) and 400 mW dissipation may have any of the following type numbers depending on the make:

1S 2068 A
BZY 88 C6V8
HS7068
LR 68H

All these are interchangeable, and all are allocated the same code number in a well-organised stores system. Thus coding can be a powerful aid to rationalisation of stores.

Selection of Coding System

There are many technical stores in the BBC. Some of them (e.g. Equipment Department Stores and Television Stores) are already using coding systems. Other Stores are considering doing so.

As a part of the CEMAST project, and to rationalise the situation, the E.A.D.C. authorised the development of a coding system for the whole of Engineering Division. After a study of a number of coding systems, including that used by NATO, it was decided that a simple extension of the system used for electronic components in Equipment Department Central Stores would satisfy all requirements. An advantage of retaining the basic structure of this existing system is that its main classifications are already familiar in Engineering Division.

Equipment Department Code

The existing Equipment Department coding system used for electronic components has nine digits arranged thus:

$$A - BCDEF - GHI$$

The first digit, *A*, is the Central Stores group number, the second group, *BCDEF*, is the Standards Catalogue sheet number which identifies the component and the final group, *GHI*, is a suffix number which indicates the size or value of the component.

Extended Code for CEMAST Project

The extended coding system recommended for CEMAST employs the same sequence of digits as in the Equipment Department code but arranged as groups of one, four, and four digits, together with an additional final check digit which brings the total of digits to ten. Thus the arrangement can be indicated:

$$A - BCDE - FGHI - J$$

The first digit, *A*, indicates the Stores group number as before, the second group, *BCDE*, indicates the main classification of the item, the third group, *FGHI*, provides a second stage of classification and the final digit, *J*, is for checking. For example, the final digit may indicate the units part of the sum of the previous nine digits, and thus can be used to determine whether an error has been made in quoting a code number. The form of the code makes it easy to distinguish from that used by Equipment Department. Further details are given in the Appendix.

Practical Test of CEMAST System

The third stage in the implementation of the CEMAST programme was a practical test of the effectiveness of an integrated inventory-control system using a computer and incorporating not only the inventory-recording, forecasting and ordering procedures but also inventory acquisition, accounting, and progressing facilities. This was carried out in the Valve Stores located at Motspur Park, Surrey, and a system was devised in which the computer reviews the inventory situation weekly and automatically adjusts the re-order levels at the central store, simultaneously monitoring the inventory levels at the sub-stores.

Fig. 2.1 shows in a very simplified form how the stock levels at the various stores and sub-stores are maintained at safe levels. For each store there is an automatic 'topping up' procedure in which the replenishment is dependent on the rate of withdrawal. Each store has a feedback loop analogous to the velocity feedback used in electromechanical systems. More details of the Valve Stores system are given in Chapter 3.

This system enabled investment to be reduced by £60,000. When the first phase of the computer inventory control procedure was introduced in March 1966, about 2,400 types valued at £334,000 were held at Valve Stores. Since that time the number of types has increased to about 4,000 due largely to the rapid increase in the number of semiconductors and similar devices recently introduced for colour-television equipment. Despite this increase the success of the first phase of the computer control system can be gauged from the fact that by December 1967 the value of stock held had decreased by about 20 per cent and the more varied inventory was handled by the same staff.

As a result, the E.A.D.C. agreed toward the end of 1967 that the Valve Stores experiment had shown that a computer system could be of value in inventory control. The success of the system was made public by Director of Engineering on 28 June 1968 at a press conference in which International Computers Limited participated.

Comprehensive System

The extension of the CEMAST project to its fourth and major stage, the purchase, storing and distribution of all engineering materials, has now accordingly been authorised and a general outline of this comprehensive system is expected to be ready by the end of 1970.

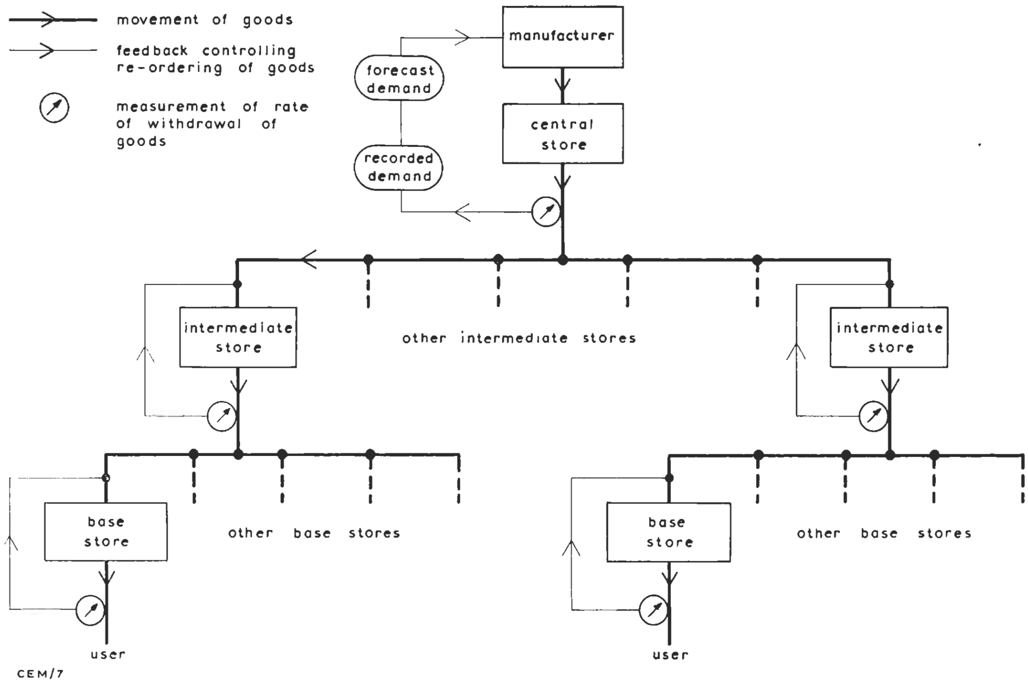

Fig. 2.1 Simplified illustration of the CEMAST valve-stores system

3

VALVE STORES INVENTORY-CONTROL AND FORECASTING SYSTEM

Introduction

The Valve Stores at Motspur Park were selected as the testing ground for a computer-based inventory-control system because their existing machine-accounting procedures were reasonably well developed, and a form of manual smoothing (known within the Corporation as the 'travelling requisitions' system) was already being used for forecasting future demand. These accounting procedures had been introduced a year earlier and had substantially reduced the value of the inventory held.

Also it was clear that the range of valves, semiconductors, cathode-ray tubes, camera tubes and similar devices was increasing considerably with the planned expansion of the Corporation's television transmissions in monochrome and colour, the duplication of BBC-1 on u.h.f. and the modernisation of shortwave transmitting stations. In fact, the annual cost of valve purchases increased from £500,000 in 1964 to £1,250,000 in 1968. Consequently it was considered that if further economies in inventory maintenance could be achieved by a computer, considerably greater savings might be expected when the system had been fully developed and applied to all Engineering Stores.

Use of Computer

Although a computer was necessary primarily because of its speed in carrying out calculations, the use of a computer has other advantages. For example it can solve problems in logic and has an electronic or magnetic store in which data and instructions can be retained.

A computer has a number of input channels in which information (data or instructions) is converted into electric or magnetic pulses for use within the equipment. Similarly there are output channels in which pulses are reconverted and presented in visible form for human interpretation. A control desk enables the computer operations to be observed and monitored.

Principles of System

The Inventory Control and Forecasting System was designed as an integrated system which covered all aspects of Valve Stores control but could be implemented in sections as the necessary development and programming work was done. The complete control system comprises a suite of programmes of which the I.C.L. *SCAN** system is the centrepiece. It is an adaptive control

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* *SCAN* stands for 'Stock Control and Analysis on Nineteenhundred', a reference to the I.C.L. 1900-series computer used.

system incorporating routines for the regular updating of stock records and the regular and automatic revision of re-order levels and quantities for each type of item.

The object is to provide a centrally-operated control system that automatically adjusts the levels of inventory held at sub-stores and in the central store in proportion to the rate of withdrawal. It automatically replenishes site inventory, and as the need arises re-orders from suppliers by printing purchase orders for the central store. Thus the computer operates as indicated in Fig. 2.1 and avoids the necessity for the complex ordering procedure illustrated in Fig. 1.5.

Description of System

The system incorporates four main procedures which can for convenience be considered separately though they are in fact interdependent in the total process. These procedures are carried out weekly and are:

1. Recording and Ordering

Information on all items in the inventory (roughly 4,000) is held on magnetic tape in the computer system, and is processed once a week to cover new items, deletions, alterations, issues and receipts. Stock levels are automatically examined and items re-ordered as necessary to replenish the inventory. Various checks are also included in the procedures.

Factors taken into account are stock in hand, stock on order, shortages, requests for special schemes, forecast demand and minimum order quantity. For each item the average price and the re-order time are re-computed. A specially-developed programme takes past delivery trends into account and smooths the effects of sudden changes which could otherwise result in under- or over-stocking. Various lists are produced which show the state and character of the complete inventory after each updating.

2. Accounting

From the issues which have been confirmed and recorded in the previous process, issue notes are automatically printed out for items to be despatched to the sub-stores, and cost figures are derived and stored in a special file held within the computer system, which includes information on sub-store or customer identity, annual operating rate, scheme number and value, and the broadcasting service concerned (i.e. BBC-1 or BBC-2, or Radio 1, 2, 3, or 4, or other services).

3. Acquisition and Progressing

This procedure uses information from the previous process to produce, inter alia, purchase orders for suppliers and manufacturers and all the details required to progress outstanding orders.

4. Forecasting and Monitoring

This process is the kernel of the system and permits the main savings to be made by reducing inventory levels at the sub-stores and the central store without reducing the standard of service. It is carried out weekly and is based on the previous month's usage at all sub-stores. It associates this usage with several other factors such as a two-year demand history for each item at each sub-store, statistical data for each item at each sub-store, total inventory held and the last re-order level. From this a new re-order level for each sub-store is calculated by using formulae derived from operational research techniques.

Included in this part of the total process is the SCAN forecasting and monitoring routine provided by I.C.L. and modified by the BBC. The SCAN routine enables the re-calculated sub-store inventory levels to be reflected in the levels of inventory to be held at the central store. It uses a mathematical method known as the 'Box-Jenkins two-point prediction formula'.

Other Features

The above is a brief and simplified version of the process, which contains several other interesting features designed to give it maximum flexibility. For example,provision is made for the acceptance of Telephoned Urgent Requisitions,known as *T.U.R.s*; these temporarily by-pass the computer system, which, however, takes their effect into account a short time later. This is important, because a computer-based system can impose undesirable rigidity if it does not allow human intervention. Every attempt has been made to keep the system flexible and to make it easy for the user to operate. A data-transmission link is provided between the Valve Store at Motspur Park and the computer room in the Langham.

4

THE FUTURE OF CEMAST

General

Systems such as that described in the previous chapter are never static, and improvements and refinements are continually being made. At present interrogation of the computer is indirect, since it involves the use of an intermediate punched-card or perforated-paper-tape input, and one of the modifications being incorporated is the provision of direct access. This will require some alteration to the valve store system and some additions and modifications to the computer, as a result of which the present magnetic tape storage will largely disappear. Increased use of data-transmission links together with the direct-access facilities will permit users to interrogate the computer directly.

It is intended over the next two or three years to extend the CEMAST project to include other engineering stores premises, with their associated monitoring facilities and purchasing, accounting and inventory-control processes. The ultimate aim is a system embracing virtually the whole of the buying, storage and distribution procedures for engineering stock items; these number about 70,000 and have a value of at least £1·5 million.

Expected Benefits

The comprehensive system is expected to permit a 10 per cent reduction in inventory value, representing a saving of £150,000. Apart from this reduction in capital investment, and the provision of better management control, the expected benefits include reduced costs under most of the following headings as detailed in earlier chapters.

1. Overstocking

The consequencies of overstocking include avoidable expenditure in connection with

(a) overhead costs of storage,
(b) deterioration and obsolescence,
(c) partial or total expiry of guarantee period before issue from store,
(d) regular maintenance of certain items while in store,
(e) slow-moving items.

2. Understocking

Understocking gives rise to avoidable direct expense when emergency arrangements have often to be made to provide priority items which are out-of-stock, and also to indirect expense because of delay and confusion when an unduly large proportion of the items required to meet ordinary demands are not available.

3. Ordering

The cost of ordering and buying routines is expected to be reduced by adaptive optimisation of the frequency of ordering and by the use of the computer to carry out such operations as automatic printing of purchase orders.

APPENDIX

CEMAST CODING SYSTEM

The general form of the codes as described in Chapter 2 can be represented thus:

$$A - BCDE - FGHI - J$$

It is not intended here to give a complete breakdown of the proposed coding system, but the following shows a few examples.

Digit A

The first digit, *A*, indicates the stores group, as follows.

0 – *not used*
1 – standard engineering stock items
2 – non-standard engineering stock items
3 – equipment
4 – *not used*
5 – *not used*
6 – items which Equipment Department wishes to code for its present accounting method until this is incorporated in the CEMAST system.
7 – *not used*
8 – *not used*
9 – *not used*

Digit B

When digit *A* is *1* or *2*, the following classification system applies for the second digit, *B*.

0 – *not used*
1 – cables and wires
2 – components (divided by alphabetical class-block method)
3 – fasteners
4 – *not used*
5 – fitments, electronic equipment, and house services (divided by alphabetical class-block method)
6 – materials
7 – tools (divided by alphabetical class-block method)
8 – specialised spares
9 – *not used*

Digit C

When A = 1 or 2 (standard or non-standard engineering stock items)
B = 1 (cables and wires)

the following classification is used for the third digit.

0 – *not used*
1 – cords
2 – equipment cables
3 – *not used*
4 – equipment wires
5 – microphone cables
6 – power-supply cables
7 – r.f. cables
8 – winding strips and wires
9 – miscellaneous

Digit D

When A = 1 or 2 (standard or non-standard engineering stock items)
B = 1 (cables and wires)
C = 7 (r.f. cables)

the following classification is used for the fourth digit.

0 – *not used*
1 – semi-air-spaced metal tube
2 – coaxial single-screen
3 – coaxial double-screen
4 – *not used*
5 – twin single-screen
6 – twin double-screen
7 – *not used*
8 – *not used*
9 – *not used*

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