UNIVERSITY OF THE WITWATERSRAND

DEPARTMENT OF MECHANICAL ENGINEERING

A COMPUTER ORIENTED INVENTORY CONTROL SYSTEM FOR MANUFACTURING INDUSTRY

by

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DECLARATION BY CANDIDATE

I, ROBIN MATTHEW KLEIN, HEREBY DECLARE THAT THIS THESIS IS MY OWN UNAIDED WORK AND HAS NOT BEEN SUBMITTED AS A THESIS FOR A DEGREE AT ANY OTHER UNIVERSITY.

R Klein

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ABSTRACT

The application of the computer to the solution of business problems has found a high level of acceptance in commerce.

This investigation attempts to illustrate the benefits to be derived in its application in industry. In particular the inventory control problem in manufacturing firms is investigated.

The flexibility and complexity of the system presented attempts to negate the possibility of optimum results being achieved using manual methods in applying the theories of inventory control. The author has attempted to show that the classical theories have very real limitations when applied to the control of components and raw materials, as opposed to the saleable end-products.

The conclusion is drawn that other methods, such as net requirements generation made practical by the advent of the computer, provide a solution and may economically justify the application of data processing equipment.

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Glossary of Data Processing Terms.

AUTHOR'S NOTE.

A number of terms used in this thesis are peculiar to the field of data processing. A glossary of these terms appears in Appendix E.

DISSERTATION

A COMPUTER ORIENTED INVENTORY CONTROL SYSTEM FOR MANUFACTURING INDUSTRY

by

R M KLEIN BSc (Eng) (Rand)

ERRATA

Page 5 Line 11 for accelarate read accelerate
Page 9 Line 12 for merchanding read merchandising
Page 27 Line 14 for statistical read statistic
Page 27 Line 19 for discreet read discrete
Page 32 Line 14 for occurances read occurrences
Page 39 Line 24 for Gausian read Gaussian
Page 45 Line 6 for prblems read problems
Page 47 Line 7 for componnents read components
Page 51 Line 15 for effectivity read effective
Page 54 Line 3 for parenthesis read parentheses
Page 77 Line 13 for repititious read repetitious
Page 117 Line 1 for Expeditng read Expediting
Page 119 Line 9 for isolated read isolate
Page 124 Line 13 for sotck read stock.

CHAPTER ONE

THE INVENTORY CONTROL PROBLEM

1.1. INTRODUCTION

The tremendous growth of the computer industry and the continuing increases in the costs of procuring and maintaining inventories have inevitably led to the application of the "super machine" to the solution of the eternal business problem. This has been done with some success and is often used to justify the purchase or hire of a computer.

With interest rates at the high level they are today, the biggest single problem in the control of inventories is the capital investment required. While it is safe to say that many companies carry excess inventories in relation to their working capital, it is simultaneously and paradoxically true that these companies have periodic back orders, uneven production rates, excessive machine downtime due to material shortages, large stock "write - downs" because of disposal of obsolete stocks and deterioration of certain materials in store. (18,7.52)

1.2. THE PURPOSE OF INVENTORIES

In the manufacturing organisation, with it's various classes of inventories, each class serves a slightly different purpose (18,7.50).

(i) Raw Materials :

This class of inventory requires further processings to make them a part of, or to convert them into, an end product. Inventories of this class must be maintained in order to

a) provide continuous supply to the processing departments
b) allow for batch production of economic lot sizes
c) permit flexibility in plant scheduling
d) speculate against price and cost changes

e) take advantage of favourable raw-material prices.

(ii) <u>Component Parts (Purchased)</u>

These stock keeping units usually require no further processing and go into the end product in the sub-assembly or final assembly stage. The reasons for maintaining inventories of these items are to

a) enable bulk purchasing at favourable prices to be made

b) ensure continuity of supply to assembly lines. These items are usually not interchangable and the shortage of even one of them leads to delays in the production of the end product.

c) handle production variations.

(iii) <u>Work in Process</u>

This category includes all product materials on which some manufacturing, processing or converting operations have been performed. Inventories of this class are usually maintained in order to

a) provide for differences in production rates between departments or operations

b) enable economic batch sizes to be produced

c) store overruns or misruns

d) allow for errors in measuring and recording

e) provide final assembly with short lead times.

f) maintain continuity of supply during unscheduled maintenance for breakdowns etc.

(iv) <u>Finished Goods</u>

These are goods which are saleable as stocked. Finished goods are stocked for the following reasons.

a) To absorb demand fluctuations and provide customer service.

b) To give customers assurance of availability.

c) To hedge against expected surges in sales due to promotions or price reductions.

(v) Expense or Indirect Materials

These items are essential to the running of the factory but are not included in the end - product.

1.3. THE COST OF MAINTAINING INVENTORIES

The maintenance of inventories would not pose a problem were there no costs associated with them. There are, however very real costs which must be minimized.

(i) Commercial Costs

(a) Capital Costs

Generally the most critical cost associated with inventories is the cost of the capital invested therein. This cost is made all the more significant in times of shortage of investment capital and of the accompanying high interest rate. Although stock is classified as a current asset, large protions of the inventory such as specialised components may not easily be disposable at cost price. A situation of serious over-stocking can endanger the liquidity of the firm.

A study by the National Industrial Conference Board on Business Policies in Inventory Management in the U.S.A. has shown that the average firm has nearly 30% of its working capital tied up inventories.

Further a study done by the writer on a sample of manufacturing companies in South Africa show that an average of 50 % of the current assets of these firms was represented by inventories (22).

The annual cost to the company of this employed capital depends on the financial structure of the firm and the rate at which it earns on its total capital employed.

A common figure in use today is approximately 10 to 12% of inventory value per annum.

(b) Insurance

It is prudent for a company to insure its stock against loss by theft, fire or other unpredictable occurances. The annual premiums on this policy is normally proportional to the value of inventory.

(ii) Storage Costs

(a) Space

In the same way that the capital employed by inventories could be effectively used in other spheres of the business, so too can the space which the inventories occupy. This cost is a little difficult to calculate but is certainly proportional to the amount of inventory held.

(b) Handling

All stock kept units must be packed, unpacked, received and issued.

(iii) Risk Costs

(a) Obsolescence

Design and technological changes made this cost an extremely important one in the manufacturing environment. It is common for parts to become obsolete by improvement in design, technology, aesthetic appeal or cost. The higher the inventory, the higher is the risk of losses due to obsolescence.

(b) Deterioration

Many items have a short shelf life and are subject to deterioration and subsequent scrapping.

The annual total of all these cost is approximately proportional tothe value of the inventory investment.

The proportionality factor currently in use varies between 20 and 25% per annum.

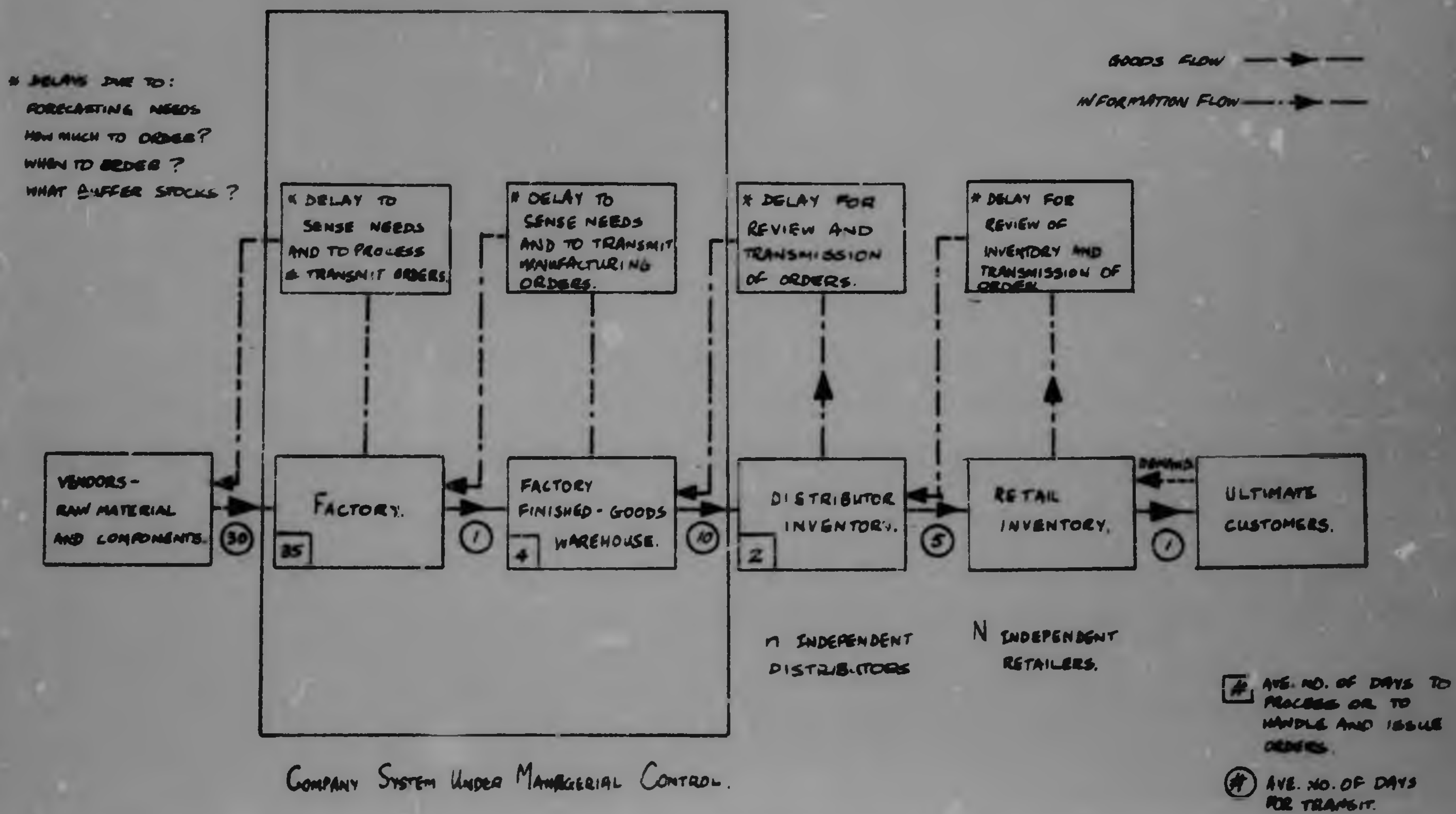
1.4. THE PROBLEM AS IT EXISTS IN THE MANUFACTURING ENVIRONMENT

In the private sector of the national economy, the largest holders of inventories are the manufacturers. This section of the economy must maintain inventories not only of finished, saleable products but raw materials, components and partly processed materials as well.

Associated with these relatively large inventories are a number of problems peculiar to the manufacturing industry. The decision of the manufacturer to cut-back accelarate his production must come in advance of the distributors to increase or decrease his stocks. He also invariably has long lead times to contend with on his basic raw-materials such as steel.. This situation is schematically illustrated in Figure 1.1 (7,220). In South-Africa the fact that she is imports dependant complicates the problem even further.

In looking at the structure of inventories it becomes obvious that the manufacturer invariably has to deal with many more different items. Naturally this depends largely on the type of product manufactured. However, for each product produced, all the components and raw materials required must be stocked. The number of items stocked thus compounds itself with its end-products. It is not uncommon for finished goods inventories to constitute only 10 to 20 percent of total inventories. This is true notwithstanding the fact that the value of finished goods include material, labour and factory overhead. In the jobbing shop the proportion will be even lower than this since finished goods

Figure 1.1 Production - Inventory System



inventories barely exist.

A few further general observations in regard to manufacturers' inventories are in order at this stage.

(i) The finished product is usually complex, and may be composed of many manufacturing levels

(ii) There are multiple uses of components, subassemblies and raw materials with significant values attached to them

(iii) Consolidation of requirements is necessary for effective inventory control.

(iv) The finished product manufacturing cycle is relatively long.

(v) Obsolescence, due to changes in design, improvement in methods and advances in technology is common.

(vi) The firm often has a complex product mix with many permutations of finished goods. (12,2)

1.5. EFFECTS OF INVENTORY CONTROL IN THE PRIVATE SECTOR ON THE NATIONAL ECONOMY.

Consulting economist Dr. Mc Crystal in his recommendation of scientific inventory control methods illustrates the significant effect inventories have on the national economy (15). He points out that "of the total increase in domestic spending in 1960 - 69 of some R6,500 million, increases in inventories accounted for 27%. More recently, of the total increase in gross domestic spending in 1967 - 69 of R1,893 million, additions to inventories accounted for 42 per cent, despite a decline in inventories in 1968".

After stressing the particular problems of manufacturers and of South Africa's dependence on imports, Dr. Mc Crystal points out that the effects on the balnce of payments may be significant.

"This is what makes scientific inventory management of such importance not only to the manager, and to the company, but to the economy as a whole.
The lower the proportion of national savings locked up in stocks, the greater the funds for investment in assets to produce more goods".

The firm must react to fluctuations in the national economy and avoid unintended investment in stocks. Many of the cyclical shortages and surpluses prevalent in raw material markets is due to users stockpiling. The effect of stockpiling is such as to exaggerate the shortage of the commodity in question. Such periods of shortages are invariably followed by periods of excess causing swings in the economy and instability in the manufacturing environment.

The relaxation of import control often leads to large build - ups in inventories. These investments may have significant effects on the balance of payments and ultimately on the countries gold reserves.

All these factors add up to an essential requirement, for the firm as well as the national economy for sound long term planning and well developed inventory management systems, especially in the manufacturing industry.

CHAPTER TWO.

THE PROPOSED METHOD OF SOLUTION AND RELEVANT THEORY.

There are a number of prewritten inventory control computer programs currently being marketed. These systems have invariably been designed for application in merchandising, retailing, spares sales and other consumer dependent operations. For this reason, the problem tackled here is one of controlling the four classes of inventory - Raw Materials, purchased and manufactured components and expense materials. Since these inventories can constitute at least 70% of total inventories, it is evident that the application of "merchanding-type" control systems to manufacturing industries will yield suboptimal results. The various models, which have been developed to answer the inventory problems of how much to order and when to order, provide good guidelines for optimising inventory levels. These models, although in their various forms cater for variables such as shortage costs, quantity discounts allowed etc., have serious shortcomings when manually applied to the "live" problem. This is especially true in the manufacturing concern.

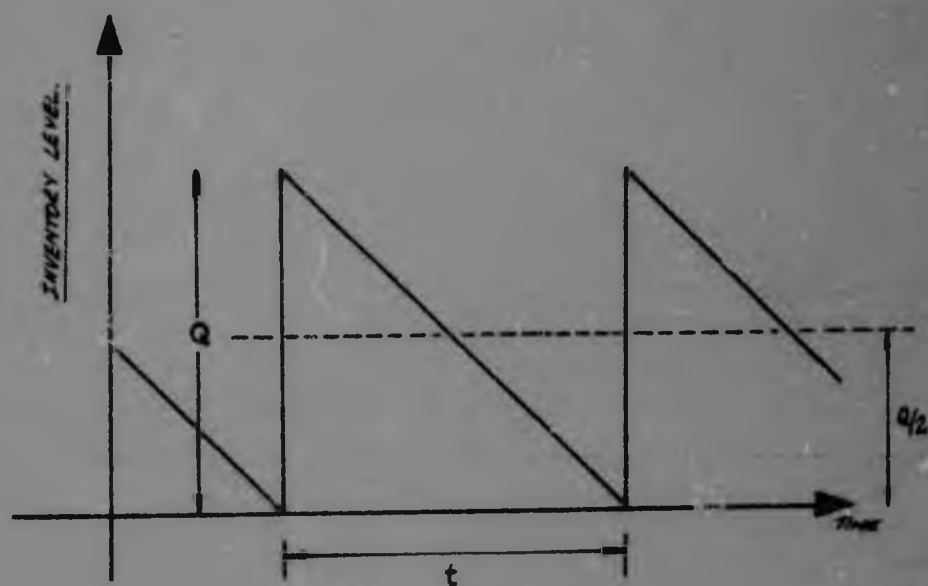
A discussion of the abovementioned models and their relevance to the manufacturing problem is in order at this stage.

2.1 THE CLASSICAL INVENTORY MODEL.

The objective of the classical inventory model as derived by F.W. Harris (10) is to determine the optimum lot size under highly idealised conditions.

The formula derived attempts to minimise the sum of the two costs of inventories, namely holding and procuring costs (7,52),

The costs of holding inventories as discussed previously are roughly proportional to the value of inventories held. If it is assumed that Q units are reordered each time, that inventories are replenished immediately the stock level reaches zero and the demand remains constant, the following inventory profile shown in figure 2.1 applies :



The objective cost function to be minimised can be expressed

Total Costs = Inventory holding costs and procurement costs.

The lot size Q is the variable which is under the control of management and the one to be optimised with respect to the other uncontrollable variables. The average inventory level maintained during the year is $\frac{1}{2}Q$, where Q is expressed in stock-keeping units.

If C_h is the inventory holding cost per unit per year, the annual costs associated with holding inventories are $\frac{1}{2}C_hQ$.

This cost indicates, as can intuitively be seen, that the holding cost is proportional to the lot size quantity Q.

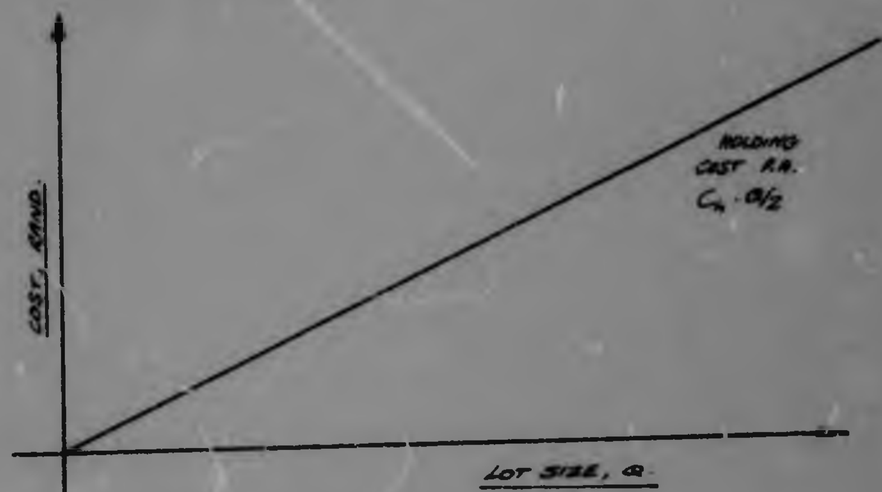


Figure 2.2

The annual procurement costs can similarly be calculated. The placement of each order and the receipt of each of the consignments has a cost associated with it. These costs involve the clerical work attached to the placement of the order, the negotiation, telephone and postal charges, unpacking, inspecting and storing charges. It is assumed that these costs are constant for each order irrespective of the size or value of the order.

Similar preparation costs are incurred in each production run, in the case of shop or factory orders.

If it is assumed that A units are consumed in one year, then $\frac{A}{Q}$ orders will have to be placed. If the cost of each order is C_p then the total order or preparation costs for the year will be $C_p \frac{A}{Q}$.

These costs are thus inversely proportional to the lot sizes used.

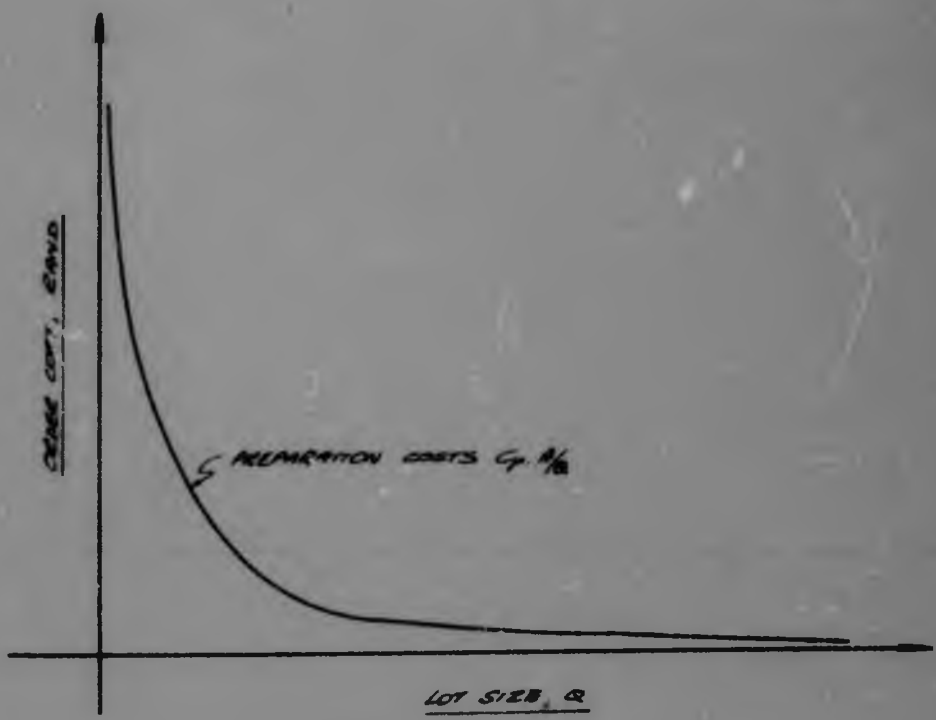


Figure 2.3

The total costs for the year are T.C. = $C_h \frac{Q}{2} + C_p \frac{A}{Q}$ can be graphically shown as the superposition of the two costs shown above.

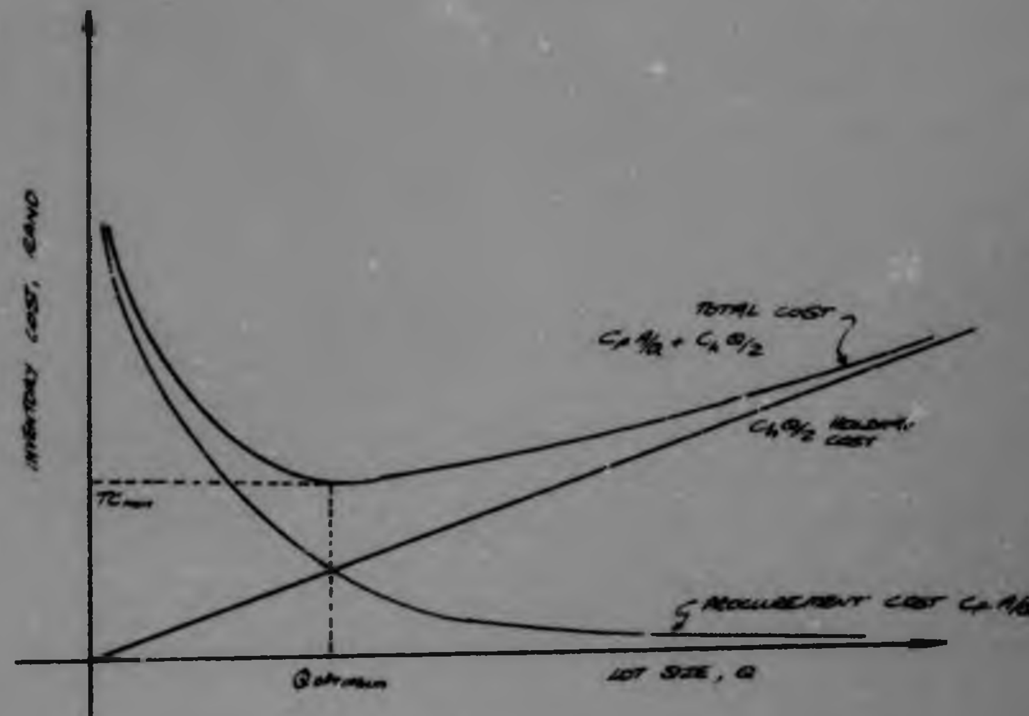


Figure 2.4

The minimum total cost can be found by differentiating the objective cost function with respect to the control variable Q.

$$TC = \frac{Q}{2} C_h + \frac{A}{Q} C_p$$

$$\frac{d(TC)}{dQ} = \frac{C_h}{2} - \frac{A}{Q^2} C_p$$

for minimum T.C,

$$\frac{d(TC)}{dQ} = 0$$

ie. $$\frac{C_h}{2} = \frac{A}{Q^2} C_p$$

$$Q^2 = \frac{2A\ C_p}{C_h}$$

$$Q = \sqrt{\frac{2A\ C_p}{C_h}}$$

It should be noted that if Q is expressed in stock-keeping units then C_h = percentage holding cost per aunum X price of stock unit.

It is interesting to note too that the total cost curve is invariably extremely flat in the region of Q_o - the optimum lot size.

This effect cancels out to a certain extent many of the inaccuracies involved in the foregoing analysis. Thus if Q_o is in error to a small degree the total cost incurred is not in error to the same extent.

This can demonstrated thus :

Total cost at optimum order quantity,

$$TC\ (Q_o) = \frac{Q_o}{2}\ C_h + \frac{A}{Q_o}\ C_p$$

Substituting for Q_o

$$TC\ (Q_o) = \frac{C_h}{2}\sqrt{\frac{2A\ C_p}{C_h}} + AC_p\sqrt{\frac{C_h}{2AC_p}}$$

$$= \sqrt{\frac{AC_p\ C_h}{2}} + \sqrt{\frac{AC_p\ C_h}{2}}$$

$$= 2\sqrt{\frac{AC_p\ C_h}{2}}$$

$$= \sqrt{2AC_p\ C_h}$$

If now the optimum order quantity was in error by ΔQ, the new total cost incurred will be :

$$TC\ (Q_o + \Delta Q) = \frac{Q_o + \Delta Q}{2}\ C_h + \frac{A}{Q_o + \Delta Q}\ C_p$$

$$= \frac{C_h\ Q_o}{2}\ (1 + \frac{\Delta Q}{Q_o}) + \frac{AC_p}{Q_o}\ \frac{1}{(1 + \frac{\Delta Q}{Q_o})}$$

let $e = \frac{\Delta Q}{Q_o}$ = fractional error

$$TC\ (Q_o + \Delta Q) = \frac{C_h\ Q_o}{2}\ (1 + e) + \frac{A\ C_p}{Q_o}\ \frac{1}{(1 + e)}$$

The total cost at order quantity Q_o can be expressed as :

$$TC\ (Q_o) = 2Y$$

$$\text{where } Y = \frac{C_h\ Q_o}{2} = \frac{A\ C_p}{Q_o}$$

$$\text{thus } TC\ (Q_o + \Delta Q) = Y\ (1 + e) + \frac{Y}{(1 + e)}$$

$$\text{and } TC\ (Q_o + Q) - TC(Q_o) = Y \left[(1+e) + \frac{1}{(1+e)} - 2 \right]$$

$$= Y\ \frac{(1 + e)^2 + 1 - 2\ (1 + e)}{(1 + e)}$$

$$= Y\ \frac{1 + 2e + e^2 + 1 - 2 - 2e}{1 + e}$$

$$= Y\ \frac{e^2}{1 + e}$$

The fractional error in total cost is:

$$\frac{TC\ (Q_o + \Delta Q) - TC(Q_o)}{TC\ (Q_o)} = \frac{\frac{Y\ e^2}{1 + e}}{2Y}$$

$$= \frac{e^2}{2(1 + e)}$$

Table 2.1

Fractional error in Q_c e	Fractional error in total cost $\frac{e^2}{2(1+e)}$
0,05	0,0012
0,10	0,0045
0,20	0,0167
0,30	0,0350
0,50	0,0830
1,00	0,2500

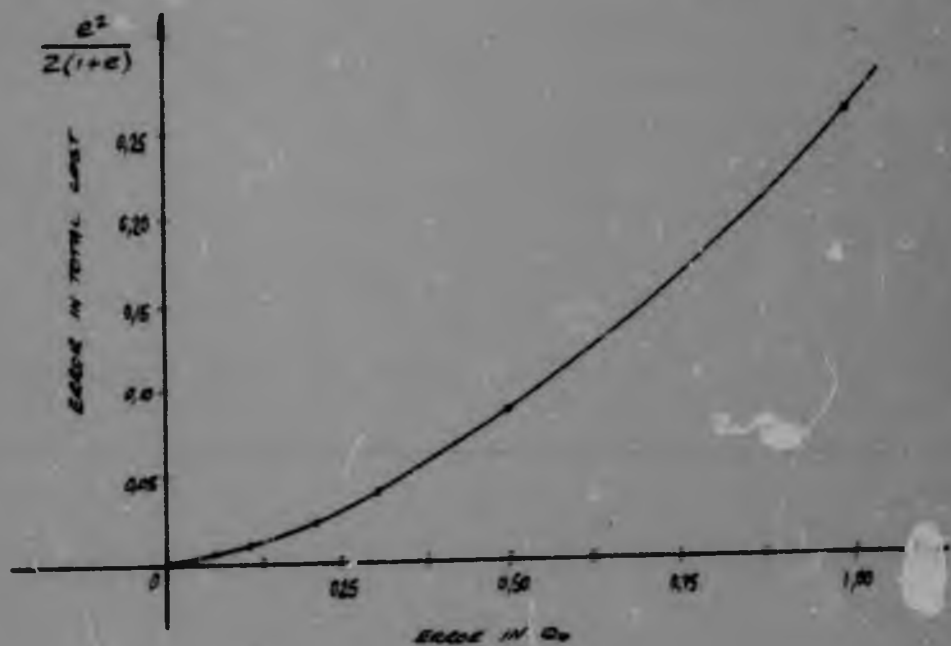


Figure 2.5

The fractional error in total cost is thus relatively small in comparison with the error in order quantity.

2.2 EXTENSIONS TO THE CLASSICAL MODEL

In order to relax a few of the rigid assumptions used to derive the classical model extensions to this model have been evolved. The assumptions include :

(i) The demand is satisfied exactly on time

(ii) The demand is constant

(iii) The price of the item is fixed irrespective of quantity.

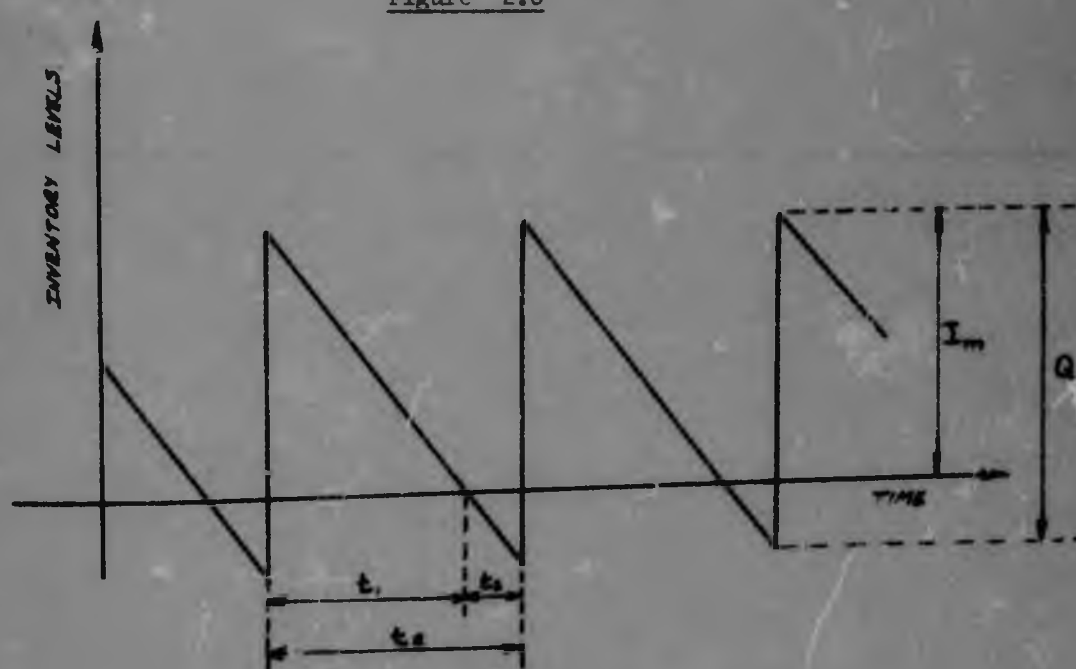
(iv) The entire order is received in inventory all at once

These assumptions have been partically overcome by models including shortage costs, buffer stocks and discount algorithms.

Shortage Costs

It is often possible to accumulate back orders and satisfy these when stock becomes available. These shortages invariably incur costs which are usually proportional to the time for which the demand is unfulfilled.

Figure 2.6



The holding cost during the period T_1 is

$\frac{1}{2} C_h I_m T_1$

$T = \frac{I_m}{A}$

Thus the holding cost is

$$C_h \frac{I_m^2}{2A}$$

Similarly the shortage cost is

$$C_s \frac{Q - I_m}{2} T_2$$

$$T_2 = \frac{Q - I_m}{A}$$

Therefore the cost of shortage during T_2 is

$$C_s \frac{(Q - I_m)^2}{2A}$$

The cost of ordering during one cycle is C_p

Thus the total cost during one cycle is

$$C_p + C_h \frac{I_m^2}{2A} + C_s \frac{(Q - I_m)^2}{2A}$$

The annual costs involved

TC = Cost / Cycle X number of cycles per annum.

$$= \left[C_p + C_h \frac{I_m^2}{2A} + C_s \frac{(Q - I_m)^2}{2A} \right] \frac{A}{Q}$$

$$= C_p \frac{A}{Q} + C_h \frac{I_m^2}{2Q} + C_s \frac{(Q - I_m)^2}{2Q}$$

$$= C_p \frac{A}{Q} + C_h \frac{I_m^2}{2Q} + \frac{C_s Q}{2} - C_s I_m + \frac{C_s I_m^2}{2Q}$$

To obtain optimal values of Q and I_m

$$\frac{\partial(\text{Total Costs})}{\partial Q} = 0 \quad \text{and} \quad \frac{\partial(\text{Total Costs})}{\partial I_m} = 0$$

This pair of simultaneous partial differential equations is solved in Appendix A and yields :

$$Q_o = \sqrt{\frac{2C_p A}{C_h}} \sqrt{\frac{C_h + C_s}{C_s}}$$

and $$I_{m_o} = \sqrt{\frac{2C_p A}{C_h}} \sqrt{\frac{C_s}{C_h + C_s}}$$

The effect of introducing shortage costs into the classical model is such as to increase the optimum order quantity by the factor $\sqrt{\frac{C_h + C_s}{C_s}}$

In the classical model C_s is assumed infinite and $\sqrt{\frac{C_h + C_s}{C_s}}$ tends to one.

The shortage costs associated with components required for assembly in an end product may be considered infinite. However if a substitute component is available at a reasonable cost, the shortage cost may have a finite value, thus affecting the maximum inventory and optimum order quantities (7,59).

Quantity Discounts

If the price of the stock item is included in the classical formulae, a further variable is introduced when this price is subject to quantity discounts as is often the case.

Holding cost C_h when expressed in terms of price = $F_h P$

Where P_h is the holding cost expressed as a fraction of item value per annum and P is the price or standard cost of the stock item.

P is not usually a linear variable since price "breaks" occur at various order quantities. The relationship of P to Q is illustrated in Figure 2.7 for a typical item subject to quantity discounts.

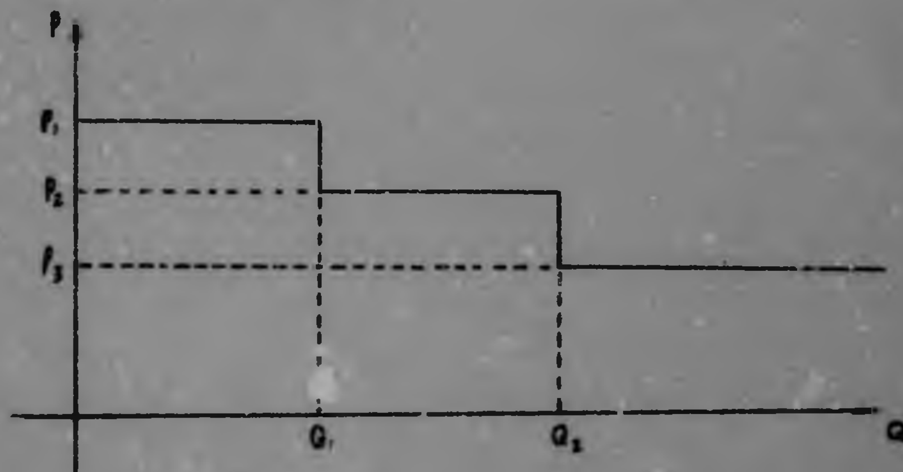


Figure 2.7.

An iterative procedure is necessary to determine the optimum order quantity in this case. This procedure is a complex sequence of computations in the case of 2 or more price breaks. (Reference 7, Pages 60 - 64).

Variable Demand

The factor A, in the classical model is assumed constant and entirely predictable. However the variability and uncertainty of demand is a most crucial factor in the development of an inventory management system.

If A is the average annual demand expected, then if the demand distribution is symmetrical and Gaussian, then demands greater than A are as likely as demand less than A.

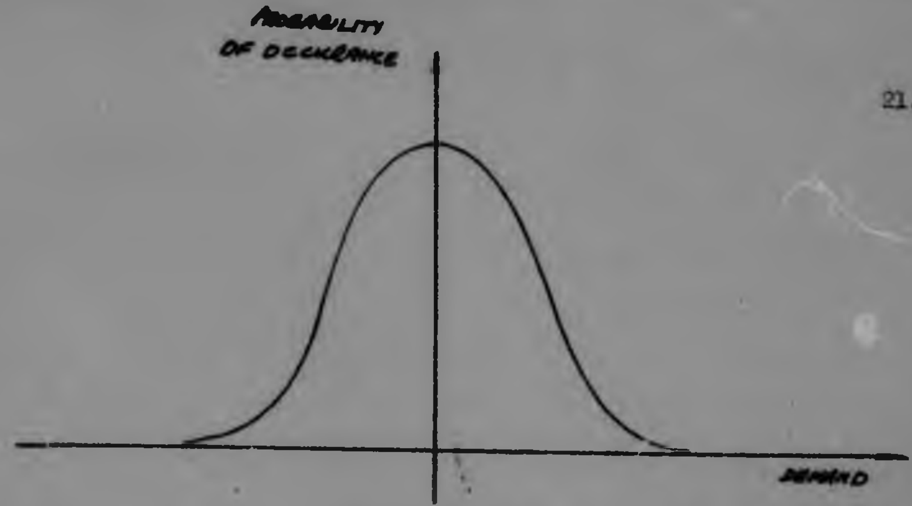


Figure 2.8

An additional component of inventory is required to reduce the risk of "stock - out" during periods of demand exceeding $\bar{A}$. This component is commonly called buffer or safety stock.

A further consideration is that of the time required to procure supply of the stock item from the supplier. This time, the lead time is also a variable statistical in nature which affects the decision of when to order.

Figure 2.9 below illustrates these two components of inventory management.

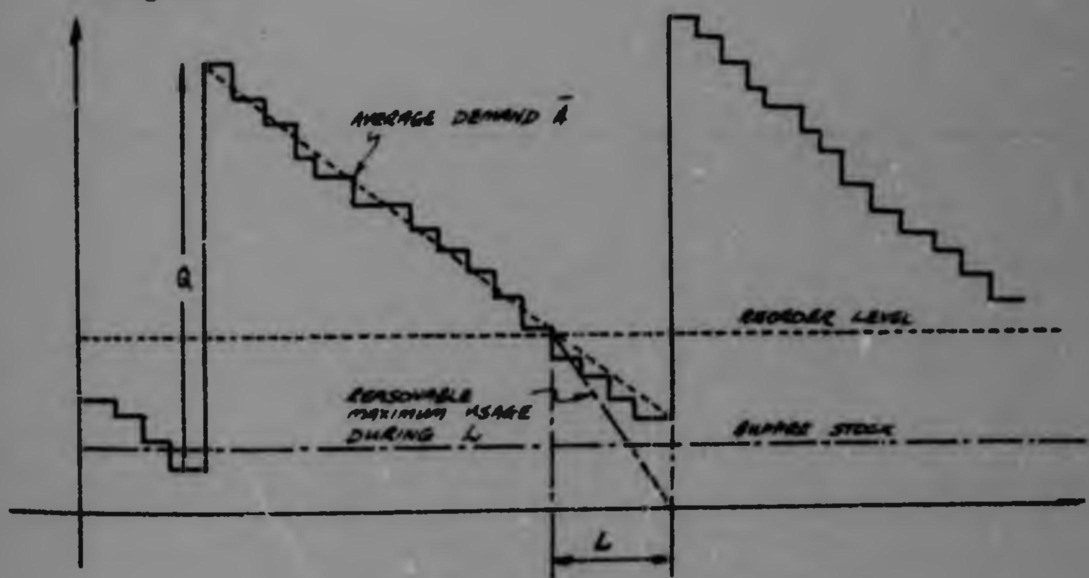


Figure 2.9

Catering for any possible demand implies maintaining infinitely large buffer stock. Thus a "reasonable" maximm usage must be estimated. The normal or Gaussion distribution has been found to describe most demand functions adaquately at the factory level of the production inventory system. Knowing the characteristics of the demand distribution e.g. the mean and standard deviation, enables the probability of any particular demand being exceeded, to be predicted.

The cumulative distribution shown in Figure 2.10 below illustrates this point for the case of a normally distributed demand.

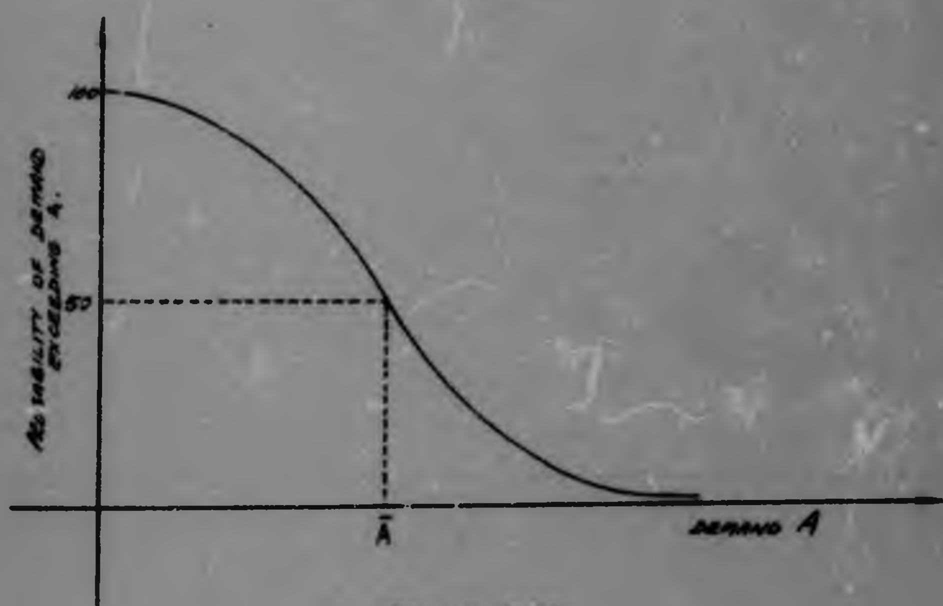


Figure 2.10

A realistic A_{max} can now be arrived at, by deciding on the level of service required. The "service level" is defined as the percentage of time continuity of supply will be maintained. For example if a service level of 99% was desired then only 1% risk of stock out would be tolerated.

Given this service level, reference to the normal distribution tables, a section of which is reproduced in table 2.2, determine A_{max}. Only the mean demand $\bar{A}$ and the standard deviation σ_A need be known to completely describe the Gaussian distribution.

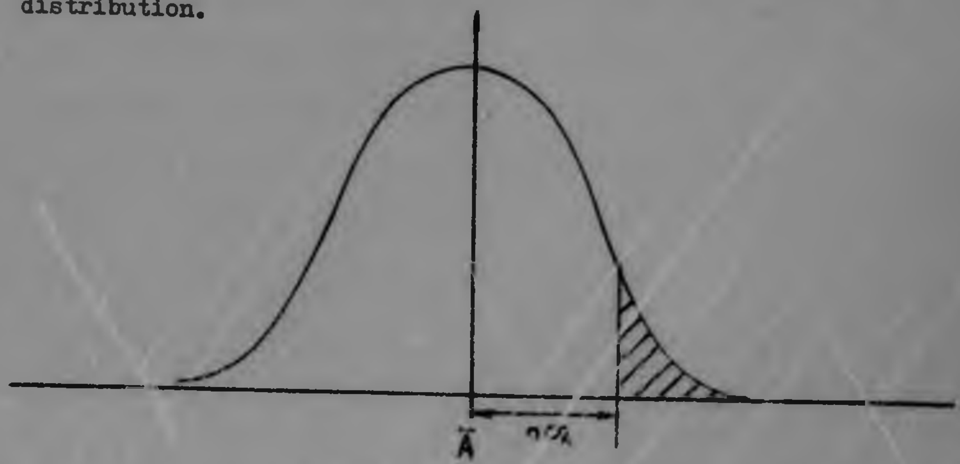


Figure 2.11

The deviation from the average $\bar{A}$ is usually expressed in terms of σ_A the standard deviation - $n\sigma_A$. The probability that the demand exceeds $\bar{A} + n\sigma_A$ i.e. lies in the shaded region of the figure 2.11 is shown in the following table.

Table 2.2

n	Probability that A exceeds $\bar{A} + n\sigma_A$
3,090	0,1 %
2,576	0,5 %
2,326	1,0 %
1,960	2,5 %
1,645	5,0 %
1,282	10,0 %
0	50,0 %

A similar table can be set up for other types of demand distributions.

Referring now, to Fig. 2.9 a decision rule for "when to order" can be derived. The item must be reordered when the available stock reaches the reorder level. This reorder level can be expressed as follows

$$R.O.L. = \bar{A} L + \text{Buffer Stock}$$

$$= A_{max} L$$

$$= (\bar{A} + n\sigma_a) L$$

where L is the lead time on the supplier.

2.3. SHORTCOMINGS OF THE CLASSICAL THEORIES WHEN APPLIED TO COMPONENTS.

How relevant is this decision rule in the control of components and raw materials required for manufacture of an end - product?

Assume the following product structure

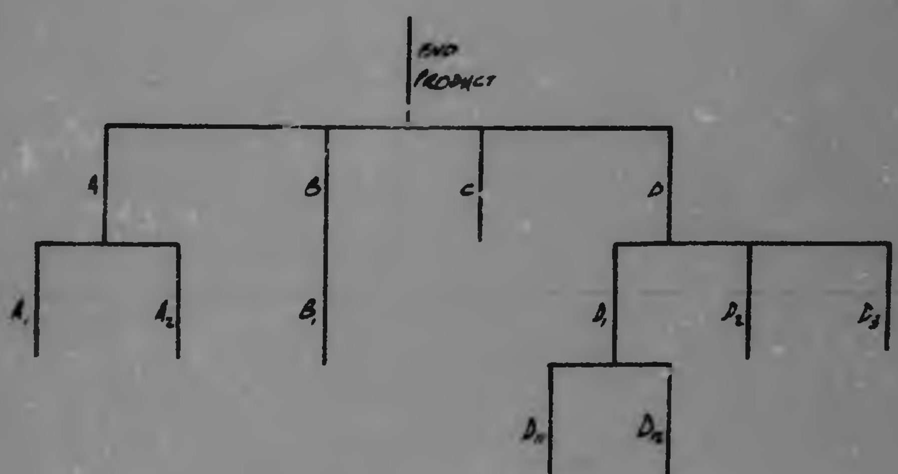


Figure 2.12

Where A, B, C, D, A_1, A_2, B_1, D_1, D_2, D_3, D_{11} and D_{12} are the components and raw materials of the end - product. A_1 and A_2 make up A, B is made from B_1, D_{11} and D_{12} make up D_1 which in turn is combined with D_2 and D_3 to make D.

Finally A, B, C and D are combined to produce the end - product.

Each of these items must be stocked and shortage of any one of them, precludes the manufacture of the end item. Thus each item must have a buffer stock and an associated service level.

Suppose a service level of 99% (n = 2.326) is decided on. This is a high service level and requires fairly large buffer stocks, depending on the variability of demand.

The service level of the final product can now be calculated.

I the probability of maintaining supply of D_{11} is .99 as well as that of D_{12} then the probability of maintaining supply of D_1 being the combination of the two is $P(D_{12})$ = .99 x .99 = .9801.

The entire network can now be calculated on this basis.

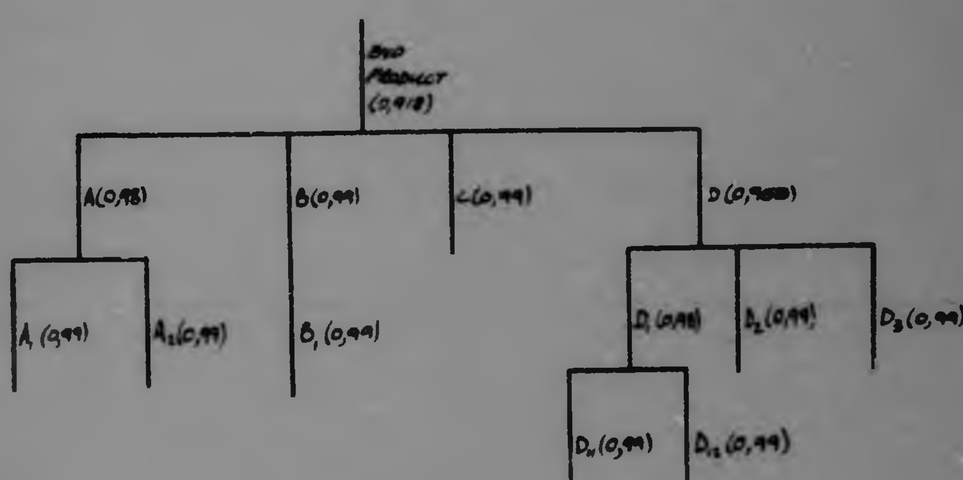


Figure 2.13.

Thus the end product can only be provided at a service level of 91.8%. The structure chosen above is an extremely simple one and the problem is usually compounded in real situations. To provide a service level of 95% on an end product would require unrealistically high buffer stocks of components were this technique used.

Using a simple one level structure this can be demonstrated for n components

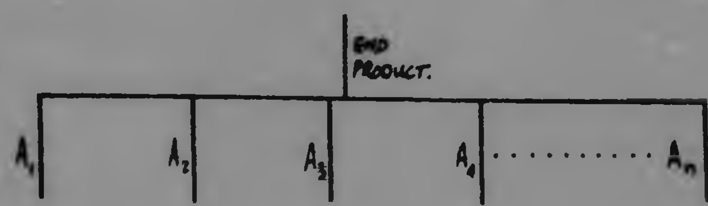


Figure 2.14

Service level of A = (Service level of A_k)^n

e.g. .95 =

The table below illustrates the service level required for the components for various values of n (ie. numbers of components making up the end product)

Table 2.3

No of components - n	Required Service Level of A_k
2	97,50%
3	98,30%
4	98,70%
5	99,00%
6	99,15%
7	99,27%
8	99,36%
9	99,43%
10	99,49%
50	99,90%

This analysis obviously invalidates the classical determination of buffer stocks for components and raw materials and leads to the concept of demand dependent items to be discussed later.

2.4. FURTHER SHORTCOMINGS OF CLASSICAL MODELS IN SPECIAL CASES

The two formulae used in the classical models indicating when to order and how much to order summarise the foregoing theory.

How much to order :

$$Q_o = \sqrt{\frac{2C_p A}{C_h}}$$

subject to shortage cost modification and discount algorithm.

When to order : $ROP = A_{max} L$

$$= (\bar{A} + n\,\sigma_a)L$$

It has been seen that A is a variable statistical in nature which can be described by $\bar{A}$ the average annual demand and σ_A the stadard deviation - if A is normally distributed. This implies that the values of $\bar{A}$ and σ_A must be recalculsulated every time an order is placed. In the case of a demand with a discreet type distribution such as illustrated in Figure 2.15 optimum results in the short term cannot be expected. Stock held in anticipation of average demand are idle in times of zero demand and subject to stockouts in times of peak usage. Example overleaf illustrates.

Table 2.4

1. PERIOD k	DEMAND (UNITS) A_k	DEVIATION $\bar{A}-A_k$	$(\bar{A}-A_k)^2$
1	5	-3,42	11,69
2	0	1,58	2,56
3	0	1,58	2,56
4	0	1,56	2,56
5	0	1,56	2,56
6	6	-4,42	19,20
7	0	1,58	2,56
8	0	1,58	2,56
9	0	1,58	2,56
10	5	-3,42	11,69
11	0	1,58	2,56
12	3	1,42	1,[illegible]
TOTAL:	19		64,85

2. Lead time = 1 period.

3. Service level = 95%.

4. Economic order quantity = 5 units.

From 1: $\sum A_k = 19$

$$\bar{A} = \frac{\sum A_k}{n} = 1,58$$

and

$$\sigma_A = \sqrt{\frac{\sum (A - \bar{A})^2}{n-1}}$$

$$= 2,4 \text{ units.}$$

From the table 2.2 for a service level of 95% Buffer

stock: $= 2,4\ (1,645)$

$= 3,95$ units.

The reorder point using the classical formul

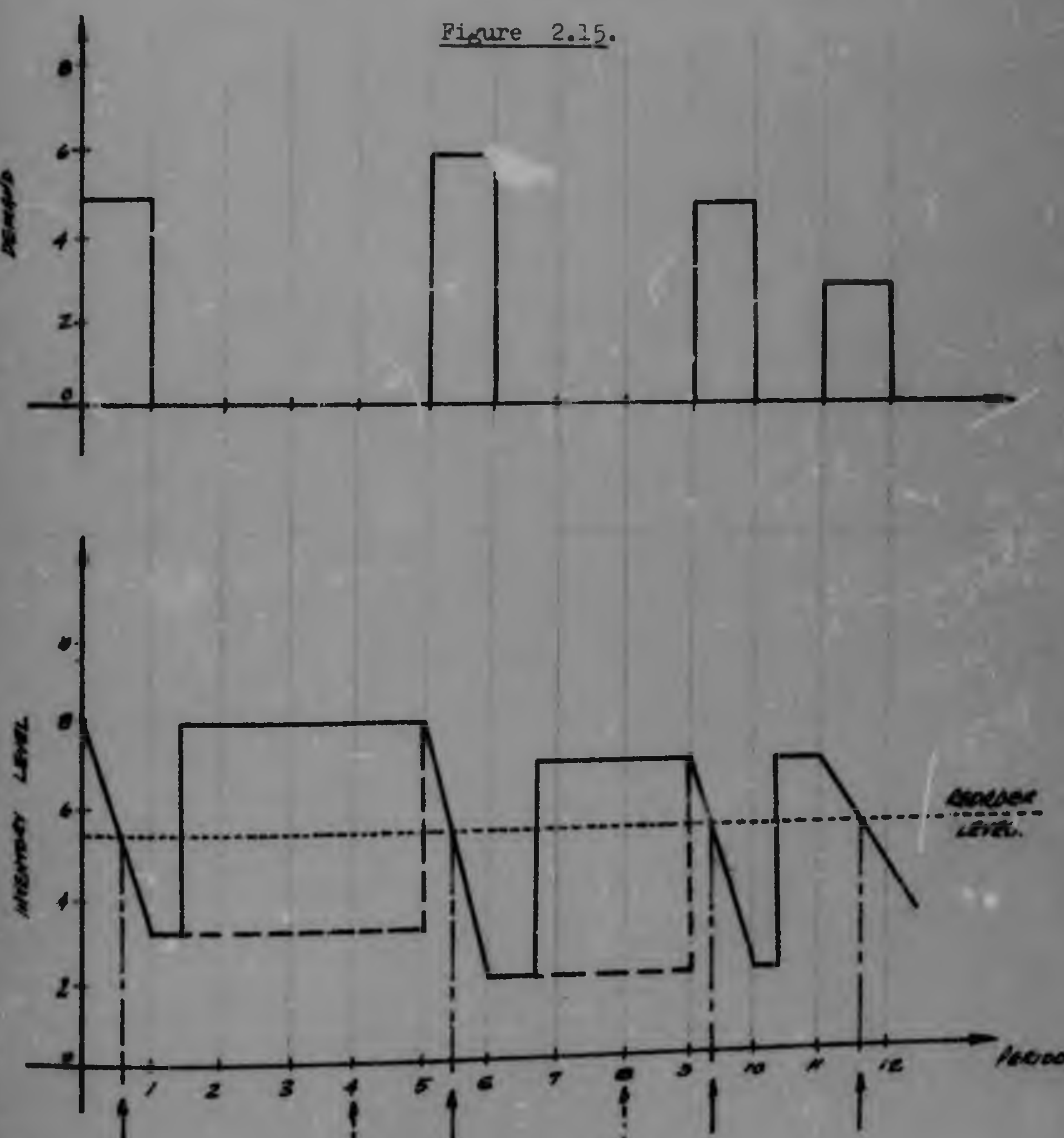
$$ROP = (\bar{A} + n\sigma)L$$

$$= (1,58 + 3,95)$$

$$= 5,53 \text{ Units}$$

In figure 2,15 the demand pulses for each time period is illustrated. The solid line inventory profile in figure 2.16 indicated the stock level over the period using the classical order point theory. The broken line illustrates a stock profile yielded when demand pulses are anticipated.

Figure 2.15.



It can be seen from the above that the average inventory held could be substantially reduced if, instead of placing an order when available stock reached reorder level, an order was placed one period (the lead time in this case) prior to the experienced demand. However this implies knowledge of when the demand is due to occur and the manitude of this demand.

Since most manufacturers who manufacture standard products adhere to a production plan the feasibility of such demand prediction becomes practical.

2.5. THE BASIC CONCEPT OF THE SYSTEM - CONTROL THROUGH PLANNING

President Eisenhower is attributed with the remark "Let's make a plan so we know what we're deviating from". This remark has much relevance in the manufacturing environment.

A manufacturing organisation whether it be a job shop, assembly (or product) line or a combination of the two, requires that all parts both manufactured and purchased, be available to meet production schedules. These requiremnts must be able to be adjusted as quickly as possible in order to respond to the changes in demand for end product.

In order to observe generality the system here presented will cater for the type of organisation manufacturing both standard and special made - to - order products. Most manufacturers, however will attempt to maintain an approximately constant level of production output. Changing the production level incurs cost such as hiring and firing, overtime costs, subcontracting, etc. It is thus usually left largely to finished goods inventories to absorb fluctuations in customer demand rather than reacting directly with changes in production output.

It can be assumed therefore that all manuf turing companies will produce in accordance with a predetermined production program. This program will naturally be subject to alteration during the course of the planning horizon. For this, and many other reasons, the computer system is designed to yield maximum flexibility in alteration and updating of this plan.

Since it is not possible for a program to be set up for items made to order, a seperate control is required for those items dependent on orders. Because of exceptions such as these, manual control of a vast number of items is impractical since a different set of rules is required for different categories of items.

By predicting, by time period the demand for each item, fine control can be effected. Orders can be placed of the correct magnitude and at the correct time enabling minimum stock to be kept.

In a firm manufacturing tens or hundreds of products, involving hundreds or thousands of items, the calculation of requirements by time period is a monumental task requiring considerable clerical effort. Updating these requirements when production plans are altered multiplies the problem.

Thus the system proposed uses a finite production plan inorder to control inventories. Only in the case of items whose use are not dependent on the production plan such as items made to order or expense, or indirect materials is a forecasting technique used.

2.6 FORECASTING.

The forecasting methods used in the proposed system are basically derived from the work done by R.G. Brown (2, 3 and 4).

Although the system uses the forecasting technique to predict only those items not influenced by the overall production plan, (e.g. expense materials, nuts and bolts etc. and all items using in the jobbing side of the business), the setting up of the plan requires considerable guidance of a sophisticated forecasting module.

The discussion following summarises the basic principles only, in the exponential smoothing forecasting technique. In the system proposal here outlined it is not intended that a comprehensive forecasting module be incorporated. Rather the techniques described are used to maintain averages, degrees of variability and trend factors.

It is assumed thatthe production program for the end-products has been set up using the more advanced techniques of double and triple averages and adaptive smoothing.

All forecasts, by their vary nature are an extrapolation of historical occurrences and are an analytical extension of the past. Common method is to use the simple average. This method may in fact be valid in a number of circumstances. For example if demands of 8, 12, 9, 10, 7, 13, 11 and 10 were experienced during the preceding 8 periods then it would be reasonable to expect that the forthcoming period will experience a demand of approximately 10 which is the simple average of the 8 demands. This method has serious limitations for most demand patterns.

Demand characteristics can be classified into a number of categories -

(i) Constant demand : This type of demand is illustrated in Figure 2.17. Random fluctuations, or noise, about a uniform and little changing average are experienced. The deviations from the average occur due to chance influences and are of a random nature.

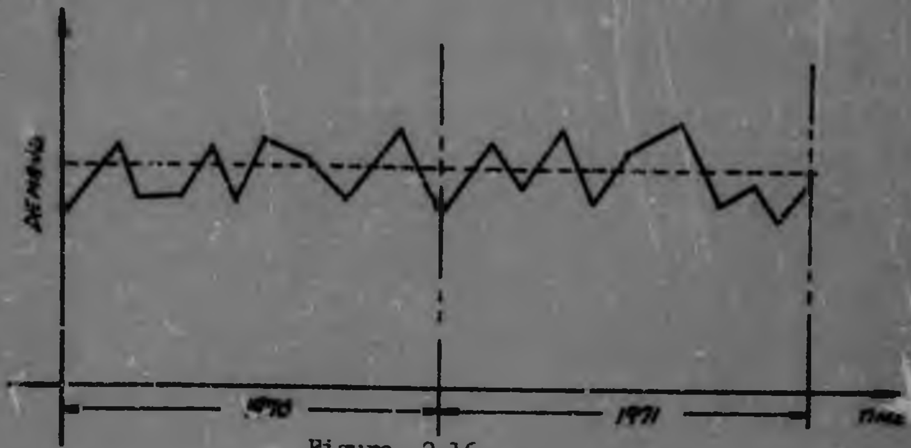


Figure 2.16

(ii) Trend Demand

A demand characteristic of the type shown below illustrates an increasing demand. This trend may be a rising or falling one. It is reasonable to expect that during the forthcoming serious demands of at least the last demand quantity will be experienced. Further it would be expected that the demand would fluctuate randomly about the extrapolated linear curve which is fitted to the past data.

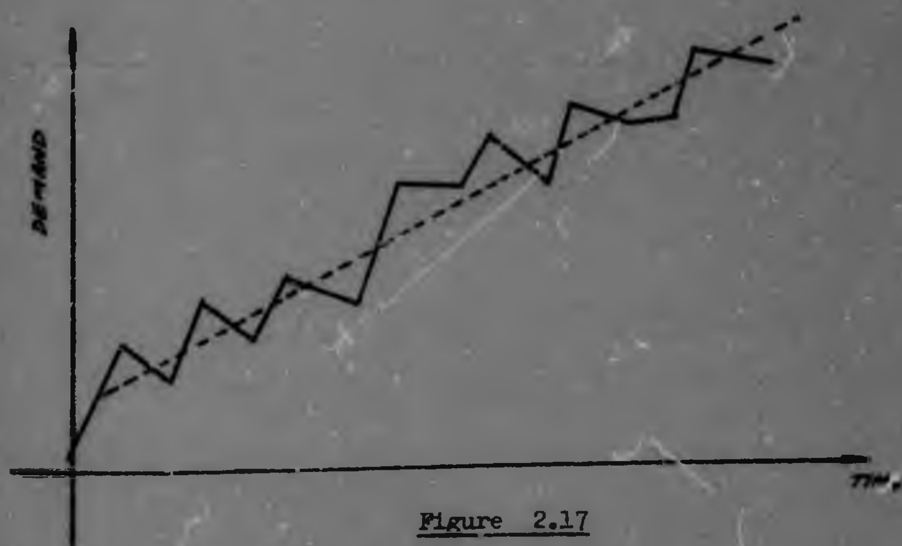


Figure 2.17

(iii) Seasonal Demand

Many products have a seasonal demand pattern. This type of characteristic can be identified by a larger or smaller than average demand recurring at regular intervals. These fluctuations from the average can no longer be attributed to isolated influences and are thus classified as seasonal.

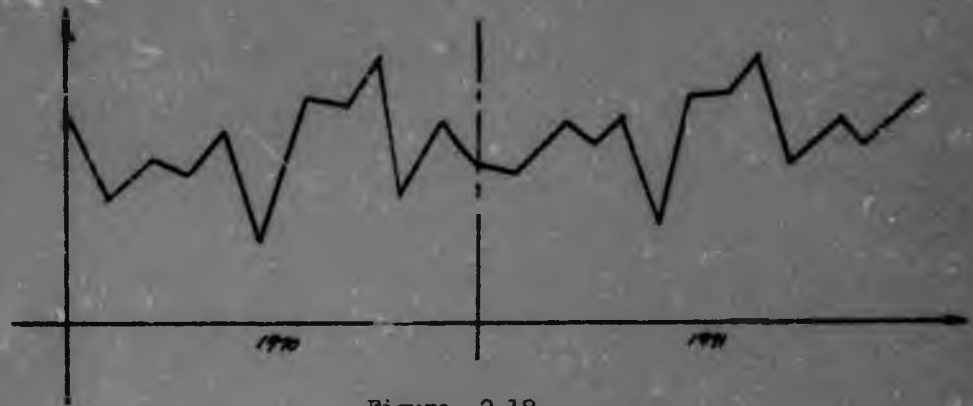


Figure 2.18

Seasonal variations are usually identified when the peak demand exceeds the average demand by more than 20% and that these special movements normally occur at constant time intervals.

Exponentially Moving Average

Normally the demand for a particular product is composed in some complex fashion of all three of the components shown above. During a product's lifetime, the demand usually displays an upward trend, a constant demand and then inevitably a downward trend.

It is obvious that the simple average is totally inadaquate method of forecasting future demand in the case where a trend is experienced.

A method is required which will take greater cognisance of more recent demand than previous demand periods.

This implies a type of moving weighted average.

Robert G. Brown developed such a weighted moving average which requires no storage of historical data since the average is updated every demand period using only the previous average and the demand for the period just passed.

The formula used is :

New Average = Old Average + α(Current Demand - Old Average)

This can be qualitatively and intuitively explained as follows. The old average is modified by some fraction, α, of the error in this old average with respect to the actual demand experienced.

This average does not ignore previous demands at all, in fact takes all such demands into account with a smaller weighting the older the demand period is. This can be illustrated as follows:

$$A_i = A_{i-1} + \alpha(D_i - A_{i-1})$$

$$= A_{i-1}(1 - \alpha) + \alpha D_i \qquad \ldots\ldots\ldots\ldots(1)$$

similarly,

$$A_{i-1} = A_{i-2}(1-\alpha) + \alpha D_{i-1} \qquad \ldots\ldots\ldots\ldots(2)$$

Substituting (2) in (1):

$$A_i = (A_{i-2}(1-\alpha) + \alpha D_{i-1})(1-\alpha) + \alpha D_i$$

$$= A_{i-2}(1-\alpha)^2 + (1-\alpha)D_{i-1} + \alpha D_i \quad \ldots\ldots(3)$$

further,

$$A_{i-2} = A_{i-3}(1-\alpha) + \alpha D_{i-2}$$

Substituting in (3)- this yields,

$$A_i = (A_{i-3}(1-\alpha) + \alpha D_{i-2})(1-\alpha)^2 + (1-\alpha)D_{i-1} + \alpha D_i$$

$$= A_{i-3}(1-\alpha)^3 + (1-\alpha)^2 D_{i-2} + (1-\alpha)D_{i-1} + \alpha D_i$$

This can be extended for n periods to:

$$A_i = (D_i + (1-\alpha)D_{i-1} + (1-\alpha)^2 D_{i-2} + \ldots\ldots + (1-\alpha)^k D_{i-k} + \ldots.)$$

It can thus be seen from this last result, that although the simple relationship in (1) is used to update the moving average, this average uses all previous demand figures. The more recent the demand, the greater is its weighting factor $(1-\alpha)^k$. Since α is less than 1, $(1-\alpha)^k$ tends to zero as k tends to infinity.

The above theory is utilised to good effect in computer systems, where minimum storage of history is desirable.

<u>Smoothing Constant - Alpha.</u>

The constant α, used to modify the old average is commonly called the "smoothing constant". This constant lies between zero and one and can be chosen to suit the demand type.

The effect of the smoothing constant can be illustrated by the following example:

<u>Table 2.5</u>

Period No.	Demand	Moving Averages $\alpha=0$	$\alpha=0.1$	$\alpha=0.5$	$\alpha=1$
Initial	100	100	100	100	100
1	100	100	100	100	100
2	80	98	98	90	80
3	105	100	99	98	105
4	120	100	101	109	120
5	85	100	99	121	85
6	60	100	95	91	60
7	130	100	99	111	130
8	100	100	99	105	100
9	110	100	100	108	110

The conventional average = 99.

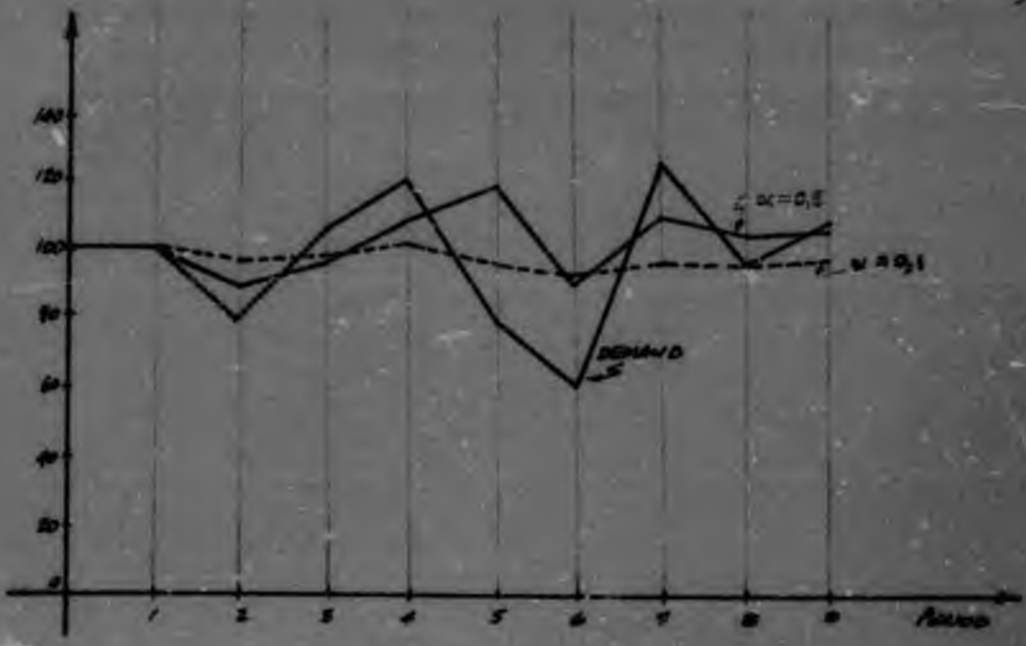


Figure 2.14

In the case where $\alpha = 0$

New Average = Old Average + α (Current Demand - Old Average)

$\therefore$ New Average = Old Average

This implies that the average is unchanging and has a value irrespective of the demand experienced.

When $\alpha = 1$

New Average = Current Demand.

In this case the forecast of demand for the next period is the same as the previous period.

$\alpha = 0.1$ yields a slowly fluctuating moving average of a fairly constant nature. When $\alpha = 0.5$, the average fluctuates substantially and responds to the sudden changes in demand.

In practice the value of α usually used is between 0.1 and 0.3. In a computer system it is advantageous to change the value of α according to the circumstances prevailing.

For example, when a new item is initiated and no historical data exists, the initial "average" will be 0. It will thus take a number of cycles before the moving averageapproaches its required value.

Table 2.6

Period No.	Demand	Forecast at $\alpha=0.1$	Forecast at $\alpha=0.5$
0	-	0	0
1	100	10	50
2	80	17	65
3	105	26	85
4	120	35	103
5	85	40	94
6	60	42	77
7	130	51	94
8	100	56	97
9	110	61	104
10	105	65	104

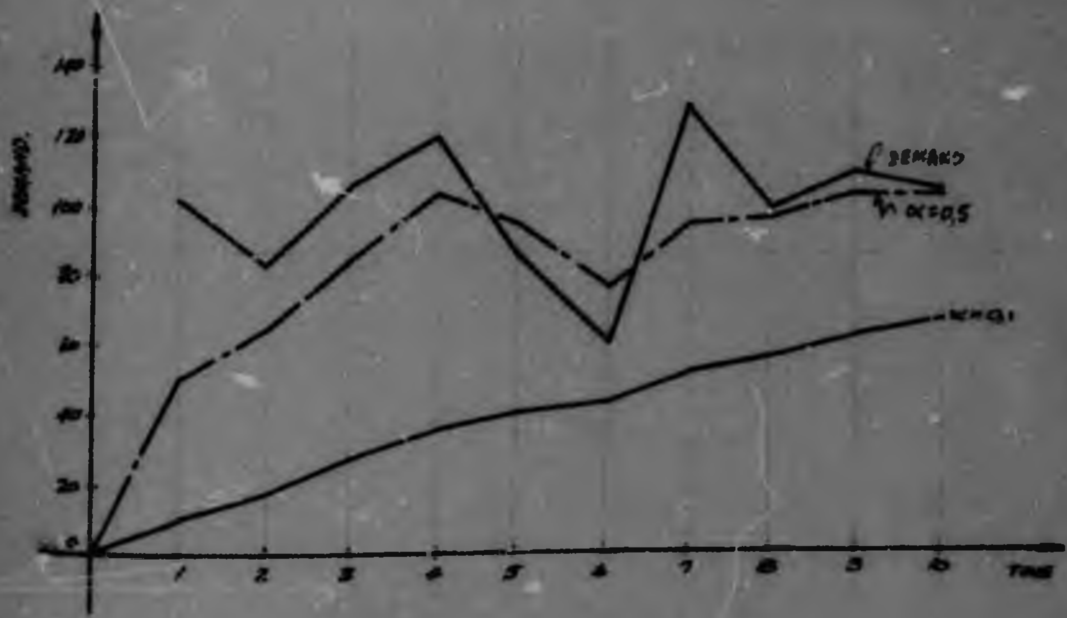


Figure 2.20

An "age counter" can be incorporated in the master record of each item. When a new item is initiated α can be set at 0.5 and maintained for a certain number of periods and thereafter can be reduced steadily to 0.1.

Measuring the Variability in Demand.

All types of demand pattern vary about the steady mean or trend line as the case may be. A measure of this variation must be maintained in order that safety stocks may be set to protect against abnormally large demands. A figure of merit similar to the statistical standard deviation is sought. Such a measure is the mean absolute deviation (MAD). This is calculated simply and is updated at each review period, similar tot he moving average.

The current deviation is defined as :

Demand this period - New average

This can be pictorially illustrated as shown below.

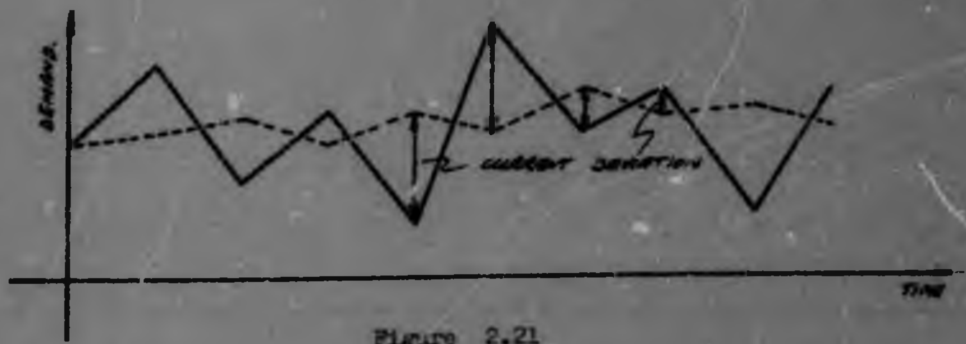


Figure 2.21

The modulus of this deviation is calculated at each review period and is used to update the moving average of this deviation in the same way that the moving average of the demand was calculated.

$$\text{New MAD} = \text{Old MAD} + \alpha \; (\text{Current Deviation} - \text{Old MAD})$$

It has been found that when the demand has an approximately Gausian distribution the MAD bears a definate relationship to the Standard Deviation.

Once again no vast storage or excessive processing need be done in order to maintain this highly responsive indicator.

Correcti for trend.

If the exponential smoothing technique is used to track a steadily increased or decreased demand, the moving average will lag behind the demand pattern. This is illustrated below.

Table 2.7

Period	Demand	Moving Average	Current Deviaition	MAD	Algebraic Sum of Deviation
Initial	-	100	-	-	-
1	100	100	0	0	0
2	120	102	18	1.8	18
3	140	106	34	5.0	52
4	135	109	26	7.0	78
5	145	113	22	9.5	110
6	160	118	42	12.7	152
7	145	120	24	13.8	176
8	150	124	26	15.0	202
9	180	130	50	18.5	252
10	160	133	27	19.4	279

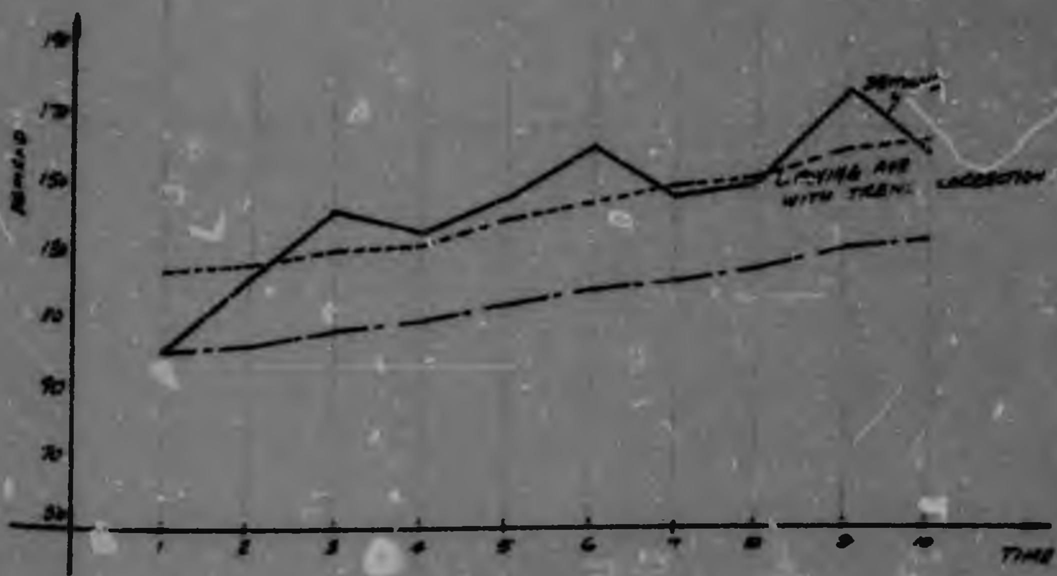


Figure 2.23

The apparent trend from one period to another is the difference in the moving average forecast from one period to the next, $A_i - A_{i-1}$. This difference is of course subject to random fluctuations. These fluctuations can be exponentially smoothed in the same manner as the average and the mean absolute deviations.

The current trend is thus $= A_i - A_{i-1}$

The average trend T_i is:

$$T_i = T_{i-1} + \alpha(\text{current trend} - T_{i-1})$$
$$= \alpha(A_i - A_{i-1}) + (1-\alpha)T_{i-1}$$

The expected demand can now be adjusted by the above calculated trend.

$$E_i = A_i + \frac{1-\alpha}{\alpha} T_i$$

where E_i is the expected demand for period i, corrected for trend.

Table 2.8 below illustrates the technique of trend correction using an arbitrary initial average trend of 3. The new expected demand is superimposed on Figure 2.23.

Table 2.8

Period	Demand	Moving Average	Apparent Trend	Ave. Trend	Trend Correct.	Expect. Demand	Current Dev.	Sum of Dev.
Initial	-	100	3	3.0	-	-	-	-
1	100	100	0	2.7	24.3	124.3	-24.3	-24.3
2	120	102	2	2.5	23.4	125.4	-5.4	-29.7
3	140	106	4	2.7	24.3	130.3	9.7	-20.0
4	135	109	3	2.7	24.3	133.3	1.7	-18.3
5	145	113	4	2.8	25.2	138.2	6.8	-11.5
6	160	118	5	3.0	27.0	145.0	15.0	3.5
7	145	121	3	3.0	27.0	148.0	-3.0	-0.5
8	150	124	3	3.0	27.0	151.0	-1.0	-1.5
9	180	130	6	3.3	29.7	159.7	[illegible]	18.8
10	160	133	3	3.3	29.7	162.7	-2.7	16.1

Seasonal Effects

For the purposes of controlling components, raw materials and expense materials seasonal effects have been ignored. Although the demand for the finished product may have a seasonal pattern, the production of such end-items would normally be of a more stable nature. For this reason it is left to the moving average to track the usage of the components and raw materials under seasonal influences.

2.7 OVERALL SYSTEM PROCEDURE.

The aim of the computer system here presented is to provide comprehensive information enabling purchase and works orders to be issued at the right time and in the correct quantities. The effect of this is to maintain minimum inventories while provide continuous service.

As by-products, reports of excesses, shortages, obsolete stocks, purchasing budgets, volume of receipts and issues can be produced. The system recognises the need for certain manual intervention and checking, to monitor the validity of data in its operating environment and it assumes that production planning personnel will be the communicators with the system.

Thewriter has found that ascientifically based inventory control system can be implemented with considerable success using limited computer facilities. It is thus the aim of this presentation to illustrate that such control is not beyond the reach of the small to average sized company. The computer used to verify the feasibility of the system was a second generation, tape oriented Burroughs B300 configuration with memory capacity of 9.6. K. bytes.

All flowcharts, file layouts etc., will be discussed in terms of a magnetic - tape based computer system, though liberal reference to random access files will be made.

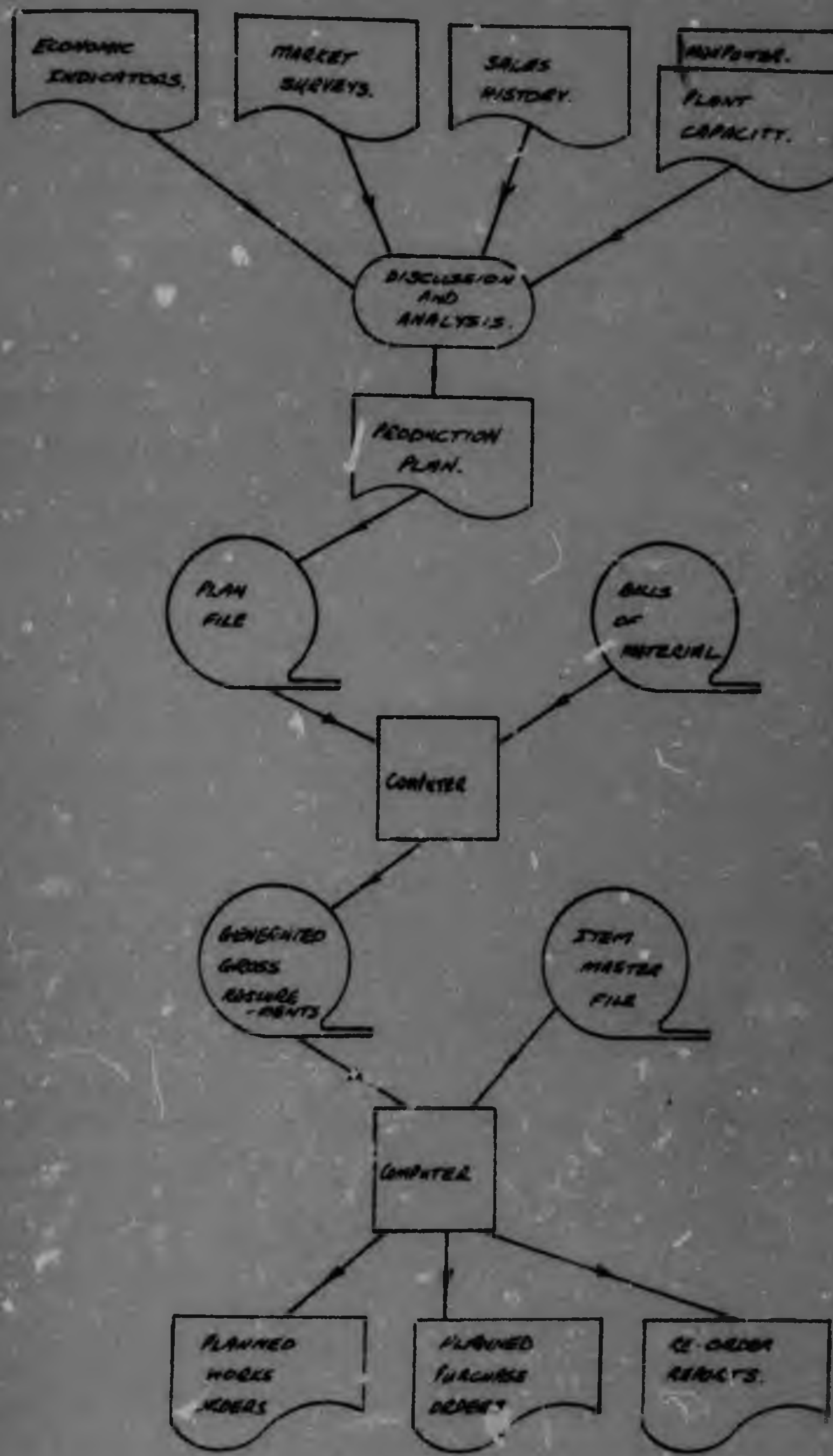


Figure 2.24 Overall System Flowchart.

The production program is used to explode the Bills of Material (Parts list) into the gross requirements of the assemblies, subassemblies, components and raw materials. Common requirements from different products are consolidation and grouped by time period.

The items for which no requirements can be generated because no program can be set up or which are demand independent such as expense and indirect materials, have their usage forecast using their demand histories.

The gross requirements are now subjected to the available stocks on hand and on order and a net requirement by time period is generated. The optimum order quantity is calculated, and an order released for that quantity.

This overall procedure must be carried out regularly. The frequency of runs depends largely on the type of manufacture (i.e long or short cycle time) and on the type of computer equipment available. On the one side of the computer scale, the tape-oriented system could probably only be updated once a week, while at the other end of the scale the "on-line" system would operate in"real time", and is in effect updated at each transaction. The broad principle remains the same in both cases.

CHAPTER THREE

THE INFORMATION FILES

The foregoing chapters presented the classical theory and approach to the solutin of the inventory control problem. It was attampted to show that these theories have very real limitations when applied to the prblems as they exist in the control of componnents and raw materials in the manufacturing environment.

In this and further chapters a possible solution to the problem will be presented. The proposed solution does not negate the classical theories but rather uses them in particular circumstances.

The key to the proposed solution is the information files, their contents and updating.

One of the primary advantages of acomputer system over a manual one is the fact that information is centrally gathered, stored and disseminated.In a manual system, information of the same type is invariably kept and updated in many different centres of the organisation in some or other form. The reason for this is that each facet of the business requires the informationin a different format or sequence applicable to their needs.

By maintaining a central information bank namely on computer, individuals can make withdrawals from this bank in the format they require. A good example is the file containing parts lists. This file is commonly required by planning and provisioning, shop floor (only the assembly or product applicable at the time), costing and engineering personnel. The problem is aggravated by the fact that each of these functional groups require parts lists in different forms. Shop floor personnel require assembly parts lists, engineering require "where - used" information, the most suitable form of parts list for costing is the summarised bill of material with the requirements of each part consolidated within each product. There are many other forms of parts lists and these will depend on the procedures within the department mentioned.

Besides requiring multiple clerical operations, the decentralised information bank leads to discrepancies and inaccuracies. The central information bank thus leads to minimum clerical updating and retrieval, as well as to greater accuracy of information. Requirements of this central information bank are that it should be regularly updated as soon after the occurance of the transaction.

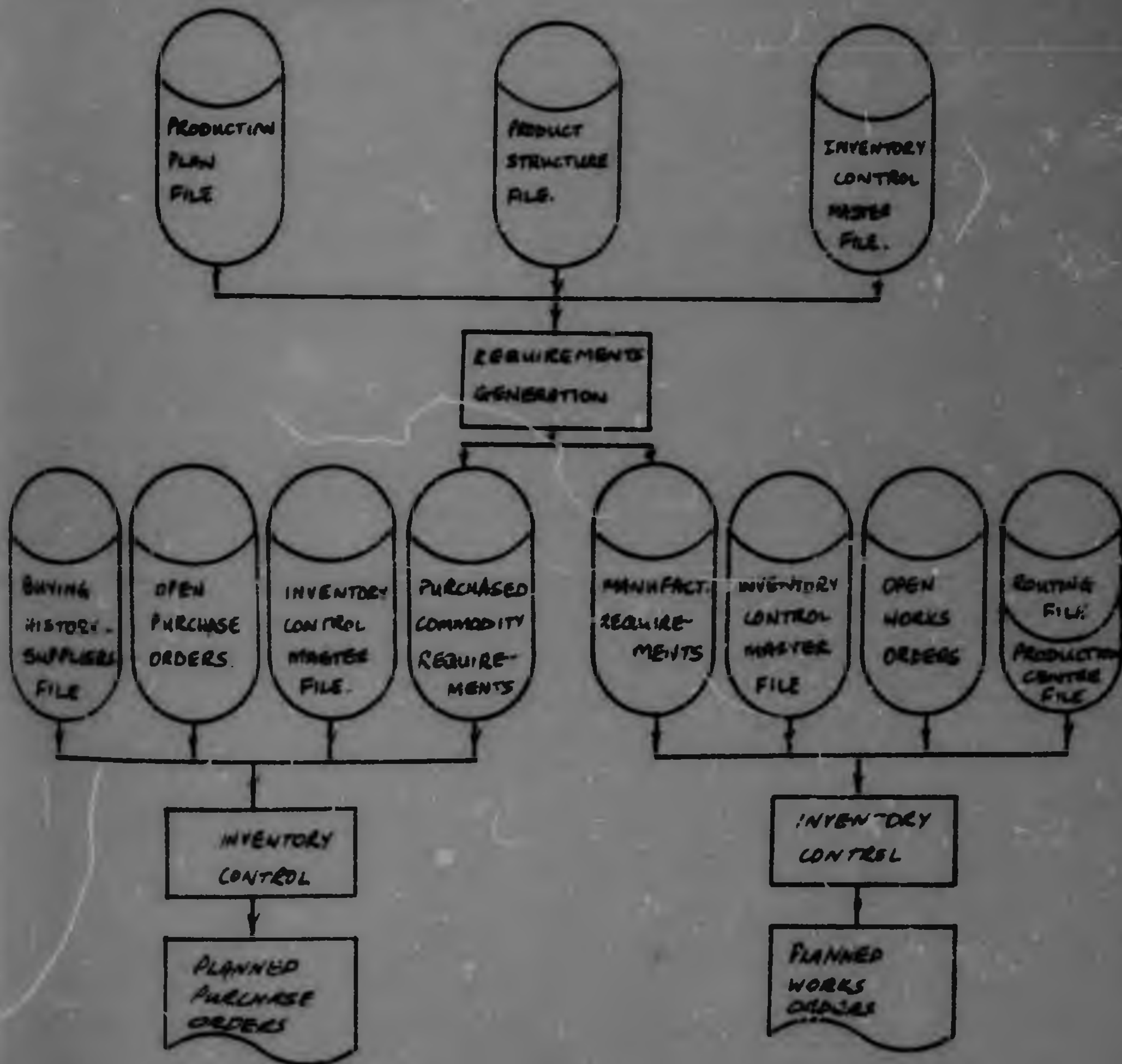


Figure 3.1

The files used and their relationship to one another are illustrated in figure 3.1 above. These files may be kept in various forms and on various types of equipment. Important here however, are the contents of the files, their updating and their mutual interrelationships.

The basic files of an information system are generally referred to as the Data Base. A Data Base covers all the operational record information needed to handle a company's business. Those presented here are by no means representative of a total Data Base. They will however exist in most manufacturing organisations in some or other form as part of the total data base.

3.1 THE PRODUCT STRUCTURE FILE :

This file contains the relationships between the various parts and their assemblies or sub-assemblies. This data can be stored in a number of ways, the most common of which in disc or random processing is the "single-level" assembly form. Each component part is related to its parent part and this link is further described by the quantity of the component contained in the parent part.

If the product structure illustrated in figure 3.2 is considered, the records showing relationship between the parts can be described in record format as shown in table 3.1.

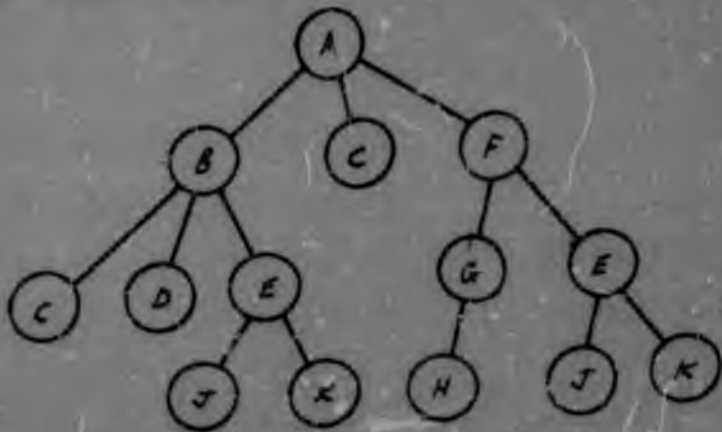


Figure 3.2.

Parent Part	Component Part	Quantity
A	B	1
A	C	2
A	F	2
B	C	1
B	D	1
B	E	4
F	E	2
F	G	2
E	J	1
E	K	3
G	H	6

In a disc oriented system only the addresses of the parts will be stored, thus linking the parts to their detailed records on the part number file.

Other fields can be included in the product structure record, such as "next component address" , "next where used address", "previous where used address" , "number of components", and "low level code". The last of these indicates the lowest level a part is found in the product structure file.

The requirements of the product structure are:

(i) that it should be easily updated, changed, added to and deleted.

(ii) retrievals from the file should be able to be economically made, for the different requirements of the people within the firm.

The layout discussed above facilitates these two requirements.

A different approach is required when processing is done sequentially, in the case where the file is stored on magnetic tape. The technique usually used is to store an entire product to all levels relating each part to the end product. The sequence of the records is important and indicates the relationship of each part to its parent.

The records describing the product illustrated in figure 3.2 are shown in table 3.2 below.

Table 3.2 - Sequentially Stored Product Stucture Records.

End Product	Component	Level No.	Quantity	Sequence No.
A	A	1	1	0010
A	B	2	1	0020
A	C	3	1	0030
A	D	3	1	0040
A	E	3	4	0050
A	J	4	1	0060
A	K	4	3	0070
A	C	2	2	0080
A	F	2	2	0090
A	E	3	2	0100
A	J	4	1	0110
A	K	4	3	0120
A	G	3	2	0130
A	H	4	6	0140

In this case the product structure file is stored in end-product sequence and each record can be uniquely referenced by the end-product number and sequence number. For example A 0090 will reference the record showing the position of part F in the product. After each update the product structure is re-sequenced.

It is suggested that further fields be introduced for inventory control application. For example apending change field should be provided with an effectivity date.

Any transaction, update or retrieval from the file should first check whether the key date is greater than the effectivity date. If this is the case, then the pending change should automatically replace the existing data.

Another useful facility is a field containing an alternative part. This can be used to good effect in the case of screws, nuts, bolts etc; or a sheet of steel with the required gauge but possibly larger offcut than the optimum sheet.

A scrap factor can also be usefully employed in the product structure record, when a certain wastage percentage is associated with a particular parent - component relationship.

The various standard formats of parts list retrievals are shown in figures 5.1, 5.2, 5.3 in chapter 5. These retrievals illustrate the great versatility of a well organised product structure file.

Care should be taken in the construction of the product structure file that excessive detail is not introduced. It is advisable to change the level in the structure only when a part or sub-assembly is held in inventory.

An example will serve to illustrate :

Figure 3.3.

If only the steel sheet and the complete bracket are stocked such that their inventory levels are known and controlled, then only these two commodities should appear on the product structure file.

In summary the product file should have the following suggested fields in its record.

1. Parent part no. or address of the part on the item file.
2. Component part no. or address of the part on the item file.
3. Quantity per parent part.
4. Next component no. or address.
5. Address of next "where - used".
6. Address of previous "where - used".
7. Level no. (in the case of sequential processing.)
8. Alternative component no. or address.
9. Pending change commodity no. or address.
10. Effectivity date.
11. Scrap factor.
12. User department code. (Can be used to create requisitions - see chapter 4.)

3.2 THE PRODUCTION PLAN FILE.

The vital plan file contains a record for each product that the company manufactures or is planning to manufacture within its planning horizon, as well as any plans for the production of spares.

Various lengths of planning horizons are used, usually dependent on the type of industry. Most industries, howevr have both a long - term and short - term plan. The long term plan can extend from one to five years. The short term operating plan usually varies between one and three months, and is subject to revision and alteration periodically.

The plan file should contain details for a period covering at least the longest component lead time. The quantities to be manufactured can be expressed in weekly, monthly or even daily terms depending on the nature of manufacture.

An example of a plan file is shown below :

Product Structure Address	Product no.	Period	Quantity	Per.	Quant.
	123456	7101	100	7102	200

....	Period	Quantity
	7206	0

In this case an 18 month horizon has been used. The format of the period number is year - month. The plan is updated monthly when any changes in the program may be included. When the month ends, the entire program is automatically shifted one month forward with an additional month being added at the end. In the example above, at the end of January 1971, the file shifts thus :

Product Structure Address	Product no.	Period	Quantity	.Per.	Quant.
	123456	7102	200	7207	derived

The additional period added to make up the 18 month horizon has its quantity derived from the preceeding 18 months and is simply the average of the quantities planned for these months. Alternatively the additional period's planned production quantity may be included in the update.

When the plan is initially set - up using marketing data, production capacity, sales trends, etc., the plan file can be used to evaluate the feasibility of the plan in terms of plant and manpower capacity as well as to budget for material, labour and gross profit. This can be simply done by combining the plan file with the inventory and operation routing file (refer to section 3.4 and Appendix) to project the cash values of material to be used, direct labour to be expended, turnover expected assuming the entire production output is sold.

3.3 GROSS REQUIREMENTS FILE

This file is generated from the plan and product structure files described in the preceeding two sections.

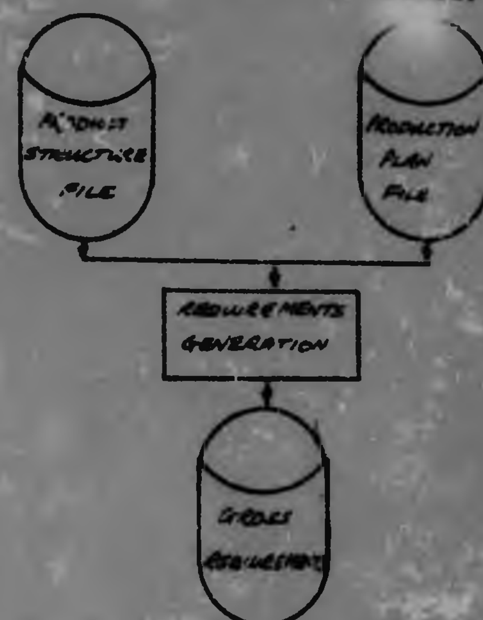


Figure 3.4

The product structure is extended by the quantities on the plan file one period at a time. Common components, assemblies and raw material requirements are consolidated by time period.

For example, if the following plan and product structures apply, the gross requirements may be derived as shown.

Plan :	Period	Product A Quantity	Product B Quantity
	1	100	Nil
	2	200	300
	3	50	100
	4	Nil	Nil
	5	200	Nil

Product Structures:

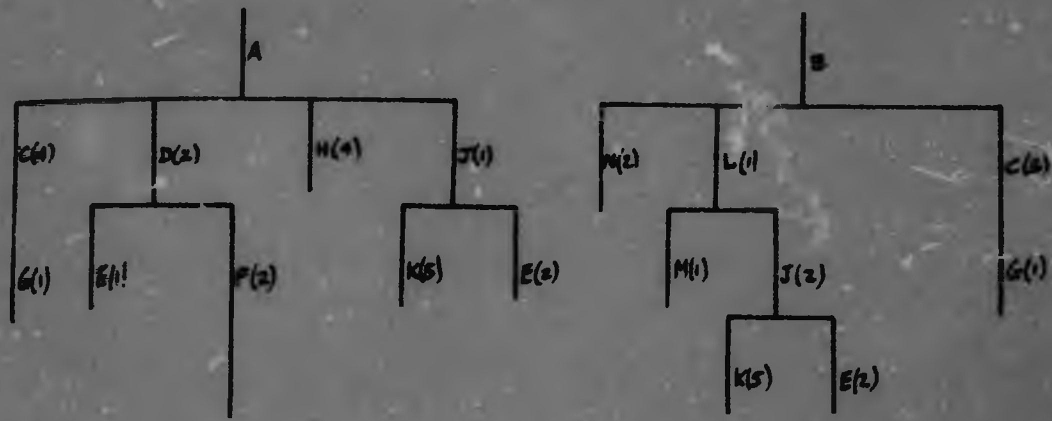


Figure 3.5

The quantities in parenthesis represent the quantity of the component contained in its parent part.

In period 1, 100 A's will be made

therefore the gross require-ments for Period 1 are:

C - 400; D - 200; E - 200+200=400; F - 400; G - 400+400=800;
H - 400; J - 100; K - 500.

Similarly for period 2:

Component	Requirements for 200 A's	Requirements for 300 B's	Total
C	800	1500	2300
D	400	-	400
E	400+400=800	1200	2000
F	800	-	800
G	800+800=1600	1500	3100
H	800	-	800
J	200	600	800
K	1000	3000	4000
L		300	300
M		300	300
N		600	600

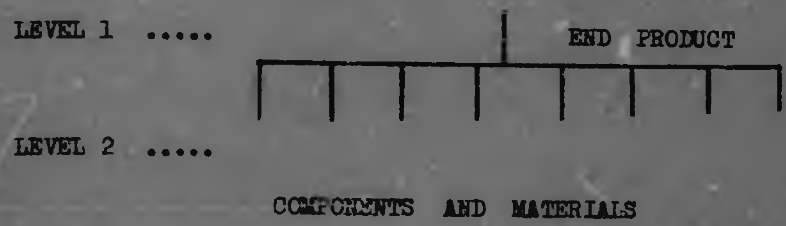
The requirements for periods 3,4, and 5 are similarly generated. The gross requirements file will be as follows:

Commodity	Period	Qty	Period	Qty	Period	Qty	Period	Qty	Period	Qty
A	1	100	2	200	3	50	4	0	5	200
B	1	0	2	300	3	100	4	0	5	0
C	1	400	2	2300	3	700	4	0	5	800
D	1	200	2	400	3	100	4	0	5	400
E	1	400	2	2000	3	600	4	0	5	800
F	1	400	2	800	3	100	4	0	5	800
G	1	800	2	3100	3	900	4	0	5	1600
H	1	400	2	800	3	200	4	0	5	800
J	1	100	2	800	3	250	4	0	5	200
K	1	500	2	4000	3	1250	4	0	5	1000
L	1	0	2	300	3	100	4	0	5	0
M	1	0	2	300	3	100	4	0	5	0
N	1	0	2	600	3	200	4	0	5	0

In addition each of the above records will contain the address of the item on the master file (Section 3.4).

The gross requirement file itself has limited use since the components and sub-assemblies may be stocked at various levels of manufacture and planning for replenishment of stock must take into account these stocks.

The "net requirements" generation described in Chapter 5 will provide the information required for the reordering procedure. Only when the items to be controlled have low level codes of 2, can the gross requirements file be directly used. This condition exists in many industries, especially in South Africa, where much of manufacture is actually assembly of bought-out components. Other examples are industries such as clothing manufacture, where only the cloth, cotton, buttons, etc., are stored, and not cut pieces and partly made garments. These continuous process products commonly have structures similar to that shown below.



In this case the available stock may be subtracted from the gross requirements to yield the net requirements and hence replenishment orders can be planned.

3.4 THE INVENTORY CONTROL MASTER FILE.

This file contains the details of all stock keeping items in the organisation. It contains much static information associated with the item as well as fields which are updated with each stock transaction.

The method and regularity of updating of this file are vital to the functioning of the control system. Ideally the file should be updated at the instant of transaction occurence. This however implies "on line" file maintainance requiring terminals communicating with the computer and accessing the records of this file on random access storage. The hardware requirements for this idealised situation are large and expensive, but are fast becoming feasible, economically.

It is practical in many cases to update this file only once per month, accumulating transaction documents during the month and batch processing at the month-end. This however does not facilitate accurate enquiry into the status of any item except at month-end; and even then the volume to be processed precludes the month-end information being available on the first day of the following month.

A successful compromise has been found, i.e. to process daily. The trans-actions for the day can be batched and processed at night. The following day the status of an item, as at the previous day-end, is available.

The details of this file are as follows:

1. Item Number.

This number uniquely defines the item and is the control field of this file. The importance of the coding of this number should not be overemphasised. A code number of this nature should have the following characteristics. It should

(a) be unique

(b) be as short as possible

(c) not attempt to fully describe the item. Characteristics of the item can be carried on subsidiary fields

(d) contain a check or verification digit. This digit is usually the last of the code number and is dependent on the preceeding numbers, according to a predefined formula. This number is checked by the computer in a verification routine, and precludes such errors as transposition.

2. Description.

A short description of the item identifying it with its common name.

3. Item Type.

A code indicating

(a) Manufactured assembly

(b) Factory made component

(c) Locally purchased item

(d) Imported item

(e) Purchased item for resale

(f) Raw material.

4. Requirements Policy Code.

This code is the key to the control procedure to be followed. The item must be analysed with respect to its controlability in terms of the predetermined production plan. If the demand for the item is independent to a large extent of the production program then its control must be effected using the conventional methods of forecast usage from past demand data and order point theory.

Examples of these latter items are: any components of special non-standard products, highly interchangeable items such as nuts, bolts, washers, pop rivets; expense materials such as brooms, rags, oils, paints, brushes, solder, welding rods. any maintenance item which must be stocked, etc. Items of this nature have a requirements policy code of 1.

On the other hand if the item is production plan dependent, then finer control can be effected as described in Section 5.3, using the gross requirements file, and the generated net requirements. In this case the requirement policy code = 1.

5. Product Group Code.

This code classifies to which product group the item belongs, and can be used without the product structure to identify, for example, the inventory value. or open orders of raw materials held solely for a particular product group. Among the codes will normally be one indicating standard item, i.e. one used on all products or a large number of product groups.

6. Drawing Number.

The drawing number is often the same as the commodity number, but this cross reference can be useful.

7. Location.

The location code here indicates the store or section of store or warehouse in which this item is commonly kept. This code can be used to produce seperate reports for different storemen showing status of only the items which concern them.

8. Bin Number.

This number pinpoints the exact position in the store where the item is stored. The despatching of items can be greatly assisted by the indication of the exact location of the item.

9. Unit of Measure.

A code to indicate the unit in which the item is kept.

for example

EA - Units; KG - Kilograms; Gr - Grams; M - Metre;
CM - Centimetres; MM - Millemetres; HU - Hundreds;
TH - Thousands; LT - Litres; etc.

10. Standard Cost-Material.
11. Standard Cost-Labour.
12. Standard Cost-Overhead.

In the case of bought-out items, the total cost price can be represented as material cost.

13. Price Break Quantity-Number 1.

The order quantity at which a discount is obtainable on the standard cost. - Q_1

14. Discount Number 1.

The discount expressed as a percentage obtainable at price break quantity number 1.

15. Price Break Quantity-Number 2: - Q_2

16. Discount Number 2.

Figure 3.6

17. List Price.

In the case of items sold.

18. Weight.

The weight per unit of the item for packing , crating and transport purposes.

19. Stock on hand.

The stock on hand in all stock-keeping locations, each recorded seperately. The accuracy and regularity of the updating of these fields is vital and a difficult practical problem. Suggested solutions to the problems are presented in Chapter 4.

20. Current Demand.

This is the demand experienced during the period between the previous status report and the coming one. For example, if a movement report is provided daily, then the current demand will indicate the demand experienced during the day in question.

21. Accumulated Demand.

The total demand experienced for this item during the review period. Any period may be used here, but it is suggested that in most circumstances a month is considered the most practical; since daily or weekly movements will tend to fluctuat too rapidly. Even if updating of this file is done "on line", all trans actions are accumulated for the review period for the purposes of averaging. Often it is not practical to record the demand, but rather the sales or issues. In such cases the demand field is not updated, only the sales.

22. Weighted Moving Average.

This is updated at the end of each review period as described in Chapter 2.

New Average = Old Average+ α (Accumulated Demand for the current month-old average)

23. Mean Absolute Deviation.

Updated at the review period end ; commonly month-end.

$$\text{New MAD} = \text{Old MAD} + \alpha(\text{ Current Deviation} - \text{Old MAD })$$
$$= \text{Old MAD } (1- \alpha) + \alpha(\text{ Current Deviation })$$

where the

Current Deviation = Accumulated Demand - New Average Demand For This Period.

24. Sum of Deviations.

New Sum of Deviations = Old Sum of Deviations + Current Deviations.

This field remains constant during the month, and is updated with all the forecasting fields at the end of the review period.

25. Current Trend.

Apparent trend after the moving average has been updated.

Trend = New Demand - Old Demand.

26. Average Trend.

New Average Trend = $(1- \alpha)$ Old Average Trend + α (Current Trend)

27. Expected Demand.

$$\text{Average Demand} + \frac{1-\alpha}{\alpha} \text{ Average Trend}$$

28. Safety Stock.

In this input field the user has one of three options provided, depending on the code specified.

The safety stock may be specified as a quantity, for example, a safety stock of 1000 pieces is required at all times. Special cases may demand this as a matter of policy for certain key items.

Alternatively the safety stock may be expressed in terms of a number of periods of average demand. For example, one month's supply. This rule of thumb is often used in practice, and may still have its application in a computer oriented system.

The third alternative is to leave this field blank. If this is the case the field "safety factor" Number 30 is used as described.

29. Safety Stock Code.

1 = Quantity ; 2 = Number of Periods.

30. Safety Factor.

If the safety stock field is blank, this field is used to calculate the safety stock as follows:

Safety Stock = Safety Factor x MAD

In this way a service level can be set.

Since the MAD is related to the standard deviation of the demand, the following table can be derived from the relationship

MAD = 0,8

and from the standard normal curve area tables (16, 9-27)

Table 3.3

Safety Factor	Service Level
3,75	99,87
3,00	99,18
2,50	97,72
2,00	94,52
1,25	84,13
1,00	78,81
0,00	50,00

The safety stock sub-routine provided is as follows:

Figure 3.7

31. Lead Time.

or procurement time. This is the time expressed in any standard time period, from the time of identification of need for resupply under the time the item is available for use, having been checked, inspected, tested if necessary and transported to the place of use.

32. Lead time Code.

This code identifies the unit of time used to express the lead time in field 31 above.

For Example:

1 = days; 2 = weeks; 3 = months; etc.

33. Turnover Category. (18, 7 - 92)

The A-B-C theory of inventory classification can be used to good effect to highlight items requiring special control. Analysis of almost all types of inventories reveal that a relatively small proportion of the total number of items account for more than half the total inventory turnover.

The following is a fairly typical distribution:

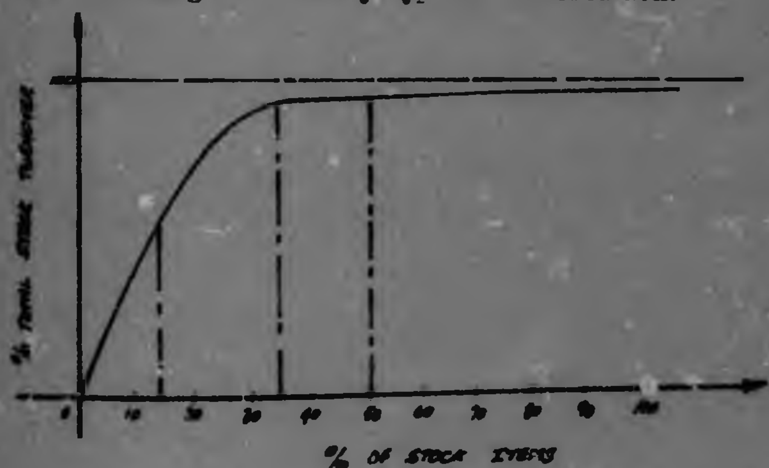


Figure 3.

This distribution will vary as the obsolescence factor of the industry varies.

A typical breakdown of inventory may reveal:

Group	Percentage of Items	Annual Turnover
A	15%	65%
B	35%	20%
C	50%	15%

The inventory may be usefully classified into three or more classes, say: A,B and C. The advantage of this stratification is that by controlling with extreme caution only 15% of the stock items, 65% of the annual total turnover can be maintained with accuracy. By the same token the "C" items, constituting only 15% of the inventory investment, yet constituting half the items, may be very loosely and cheaply maintained.

The turnover category code can be updated each month. This code can be used in various retrievals to highlight those items [illegible] special consideration.

34. Order Policy Code.

Depending on the type of item, different methods of calculating the quantity to be ordered can be selected.

The following codes can be provided:

1 Number of periods supply of past average

2 Number of periods of future requirements

3 Economic order quantity

4 Least unit cost

5 Order up-to-level

Policy 1 can be used in the case of low value expense or indirect materials where future usage can only be predicted in terms of the expected average derived from past data and updated in field 27 of this master file.

Policy 2 can be used for those items where requirements are generated from the production plan and are retrieved from the gross requirements file described in section 3.3. Limitations on the frequency of deliveries may enforce such an order policy.

For Example:

the South African Iron and Steel Corporation (Iscor) requires a quarterly order from their customers for rolled steel sheets.

If the gross requirements for an item with a 3 month lead time were as follows:

PERIOD:	January	February	March	April	May	June	July
QUANTITY:	200	500	600	350	500	550	600

and the order point was triggered, then the order would be placed to cover periods from April onwards. If the policy was set as "four months of future requirements" then an order for 2000 would be placed covering the requirements for April, May, June and July.

Order Policy code 3 is the one classically used. It is here recommended only for those independent expense and indirect materials where reliance must be placed on forecast demand.

The EOQ is calculated in the conventional manner (with or without modification of shortage costs.)

$$\text{EOQ} = \sqrt{\frac{2 \times \text{Average Demand} \times 12 \times \text{Procurement cost}}{\text{Percentage holding cost p.a.} \times \text{price}}}$$

It is suggested that a seperate routine be used to update the order quantity field at regular intervals, say three months, rather than continual time consuming updating.

The holding and procurement costs can be estimated and used for all items or may be included in this master file. (see fields 41 and 42.)

This is so if an item has exceptional expense associated with it. Order Policy Code 4 (12,25), the least unit cost method, uses the principles of the economic order quantity involving the order and holding costs.

The major difference between this policy and the EOQ method, is that the least unit cost method uses the predicted future usage, while the EOQ formula depends on the past average demand for the item. An example will serve to illustrate the iterative method of the least unit cost order policy.

The unit stock holding cost can be defined as:

$$\frac{\text{Order Cost + Carrying Cost}}{\text{Order Quantity}}$$

If the requirements for future periods are:

Period Number:	1	2	3	4	5	6	7	8	9	10
Qunatity Requd:	100	0	100	100	50	300	200	100	200	50

Assuming the order is to be placed now and the lead time applicable to this item is three periods, then the order now being considered, should cover requirements from period 4 onwards.

Assume the price of the item is R1, the order cost is R3, and the carrying cost is 2% per period. If 100 are ordered to cover period 4 only, then no carrying cost will be incurred, (since the items will be used immediatly), thus unit cost is:

$$\frac{3 + 0}{100} = \quad R0,03$$

An order covering periods 4 and 5 for 150, will incur a unit cost of:

$$\frac{\text{order cost + (price x quantity x no. of periods held x carrying rate/period}}{\text{order quantity}}$$

$$\text{i.e.} \quad \frac{3 + (1 \times 50 \times 1 \times 0,02)}{100 + 50}$$

$$\text{i.e.} \quad \frac{3 + 1}{150} = \frac{4}{150} = \underline{R0,0267}$$

Similarly for period four, five and six.

$$\text{Unit Cost} = \frac{3 + (1 \times 50 \times 1 \times 0.02) + (1 \times 300 \times 2 \times 0.02)}{100 + 50 + 300}$$

$$= \frac{3 + 1 + 6}{450}$$

$$= \frac{10}{450} = \underline{R0,022}$$

and Unit $\text{Cost}_{4,5,6 \text{ and } 7}$

$$= \frac{3 + 1 + 6 + (200 \times 3 \times 0.02)}{450 + 200}$$

$$= \frac{16}{650} = \underline{R0,025}$$

Unit Cost 4,5,6,7 and 8

$$= \frac{16 + (100 \times 4 \times 0.02)}{650 + 100}$$

$$= \frac{24}{750} = \underline{R0,032}$$

The minimum or least unit cost was obtained at an order quantity of 450, i.e. covering the requirements of periods 4,5 and 6. Expressed generally, if the requirements for period i is Ri, the price of the item is P, and L is the lead time in periods, then the unit cost for k periods is:

$$\frac{C_p + \sum_{i=L+1}^{L+k} (p \cdot C_h \cdot (k-1) \cdot R_i)}{\sum_{i=L+1}^{L+k} R_i}$$

Where C_p and C_h are the procurement and holding costs respectively.

The above is calculated for i from L+1 until the unit cost reaches a minimum. If a minimum cannot be reached with the available predicted requirements, then the total known requirements should be ordered.

Policy five - order up to level.

This order policy would only be used where it is known that the item has a definite steady demand. The quantity ordered will bring inventory level up to the quantity specified.

35. Order Quantity.

The contents of this field are dependent on the order policy selected for the item.

In the case of policies 1 and 2, this field will contain the number of periods of demand for which the order is required to cover.

Policies 3 and 4 can cause the optimum order quantity to be re-calculated at each update. Alternatively, because of the calculation and iteration involved, the optimum order quantity may be periodically calculated in a special phase. This latter method is the more economical, and incurs few errors, since the economic order quantity normally does not vary excessively over short periods.

In the case of Policy 5, i.e. " order up to level policy ", the level to which the order must bring the stock is included in this field.

36. Minimum Order Quantity.

Although the order quantity is calculated to minimise inventory costs, practical considerations may demand that an order quantity should exceed a certain minimum. One reason for this could be that the supplier cannot economically supply very small quantities, because of set-up, transport and other despatch and invoicing costs.

37. Minimum Order Quantity Code.

This code allows the minimum order quantity to be specified in terms either of a future quantity or in terms of a number of periods of average demand.

38. Maximum Order Quantity.

This limitor can also be placed on calculated order quantity for practical purposes. The modifiers of minimum and maximum can be used to good effect during abnormal periods and business cycles where, for example, inventory policies of low investment and slightly lower customer service are desired.

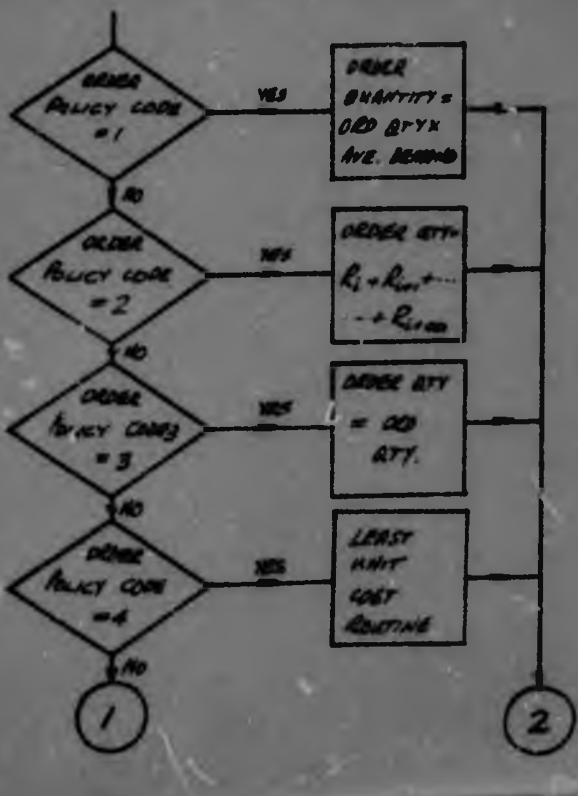
Alternatively impending changes to a product range may require abnormally low quantity orders to be placed in order to minimize the risk of obsolescence.

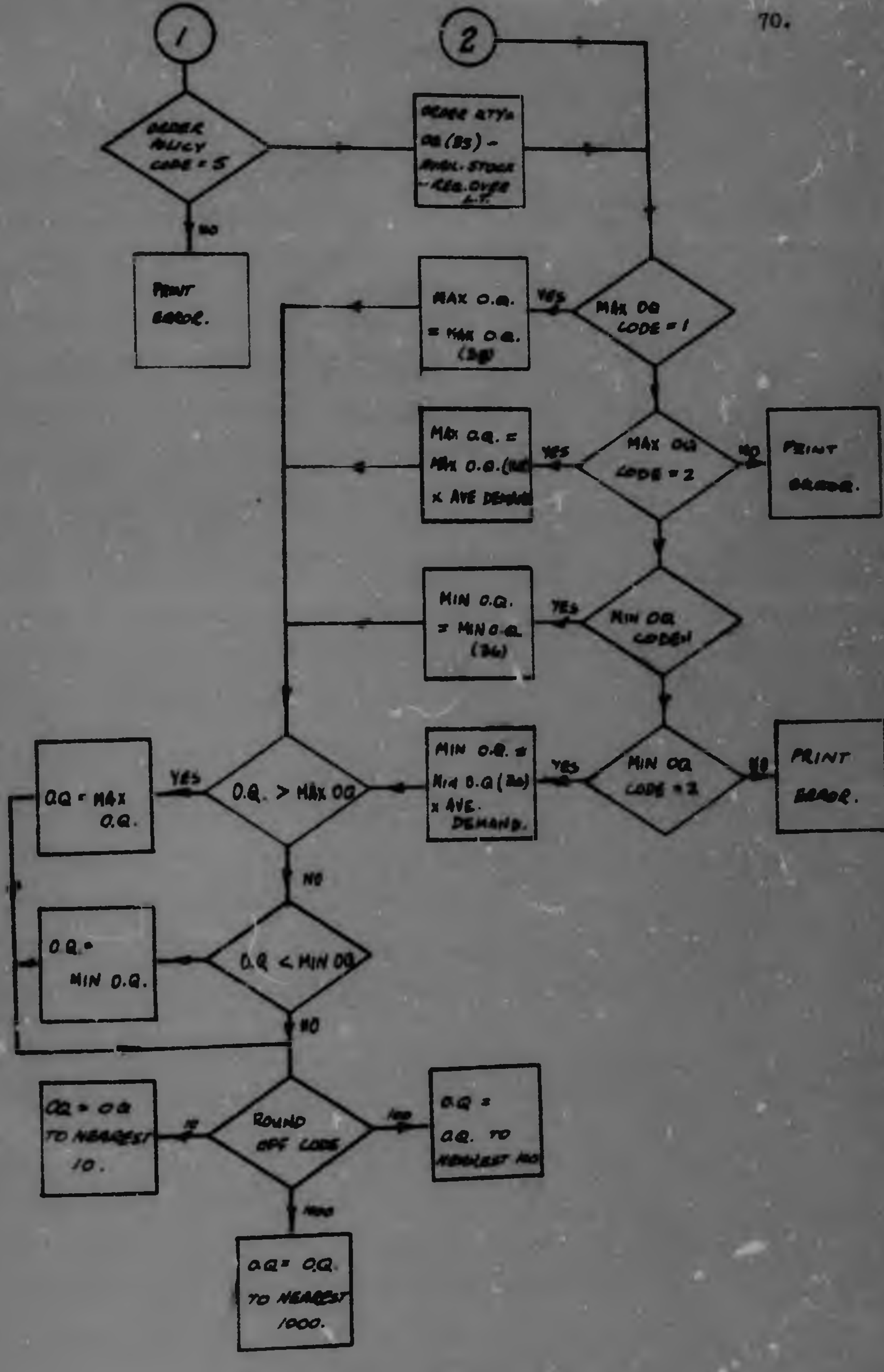
39. Maximum Order Quantity Code.

1 = Quantity; 2 = Number of periods of average demand.

40. Multiple or Round Off Code.

This code is used to round off the theoretically calculated order quantity to the nearest 10, 100, 1000 dozen, gross, etc.





Order Quantity Flowchart.

Figure 3.9

41. Holding Cost.

Expressed as a percentage of the value of the item per annum. A standard holding cost is generally used for all items. If however a particular item is subject to a larger or smaller holding cost than the normal then this cost can be specified in this field. If this field is blank then the standard holding cost is applied.

42. Order Cost.

This can be similarly specified in value terms should the ordering and/or receiving of the particular item incur abnormal order costs. In the case of factory-made components the order or procurement costs is actually the set-up cost which can be expected to vary considerably from one component to another.

43. Requirements over Lead Time.

This field is updated from the gross requirements file or from the average demand as follows :

requirements over lead time = average demand x lead time.

The lead time must first be converted to the same units as that of the average demand.

The requirements policy code in 4 determines whether future requirements or past average usage to be used.

44. Contingency Factor.

This factor expressed as a percentage is used to increase the calculated gross requirements over lead time. This facility is extremely useful as an allowance for:

(i) scrap during manufacture (ii) breakages in store (iii) pilfering (iv) evaporation or (v) spares requirements.

An allowance for this latter item may in many cases be substantial, especially where a guarantee is offered on a product or when the company runs a service or maintenance division.

The requirements are therefore modified as follows :

Total requirements over lead time == Gross requirement over lead time as in 42. X (1 + contingency factor/ 100)

45. Outstanding Orders.

Total quantity on order with suppliers or works. This field is updated from the outstanding order file which carries the line details of each order.

46. Quantity Allocated.

It may be convenient to set aside or allocate components to a particular job. Often material and component requisitions can be prepared at the beginning of the month to cover the requirements for the month's production. This stock has not been drawn, yet is allocated. (See section 4.3, chapter 4.)

Thus the available quantity is :

stock on hand + orders outstanding - allocated quantity.

Although the outstanding orders are stocks which will only be received at some future date they must be included here since an order point will be signalled until such time as the goods are received. The method used for expediting late deliveries is described in chapter 4.

47. Order Point.

Used for classical inventory control procedures i.e. when the requirements policy code = 1.

Order point = Requirements over lead time + Safety stock.

48. Planner's Code.

In larger type organisations it is common for production planning personnel each to be responsible for certain group of items (often associated with a particular product range).

The planner's code can be usefully used in reporting to each planner separately or for tracking the effectivity of the individual planner's control.

49. Critical Ratio.

The "critical ratio" is defined as

$$\text{Critical Ratio} = \frac{\text{Available Stock - Order Point Quantity}}{\text{Average Monthly Demand}}$$

Qualitatively the critical ratio gives an indication of how long the available stock will last before another order should be placed i.e. before the order point is reached.

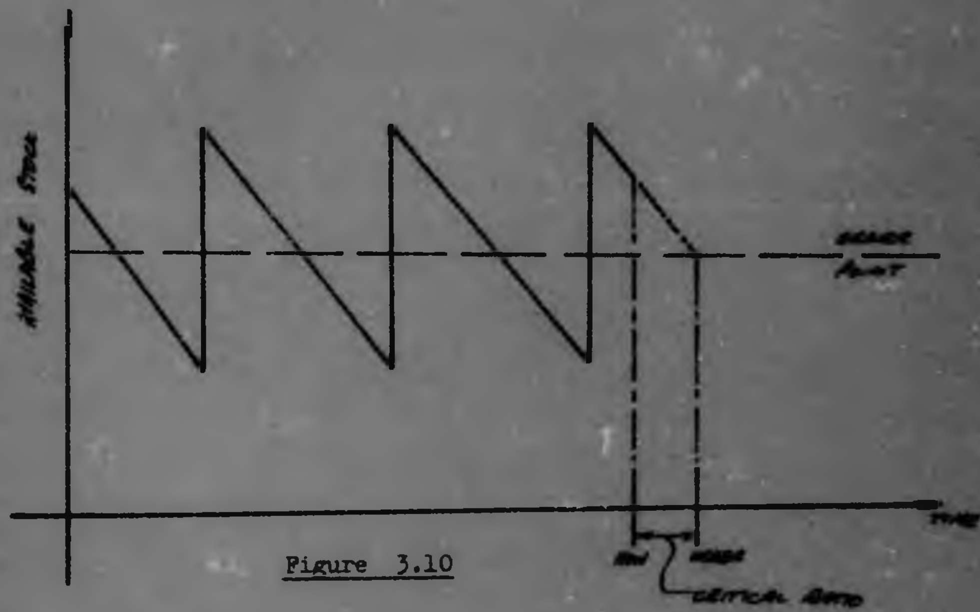


Figure 3.10

This ratio is extremely powerful in systems where updating is done in a batch mode say once per month. In this case a critical ratio ratio less than 1 will indicate that the order point is due to be reached before the next stock report is available.

50. Suppliers.

If a creditors file is available or from a good received history file the three most popular suppliers for the item can be extracted and their codes kept in this field.

This should be updated at regular intervals for example bi-annually. In the case of manufactured components or assemblies this field may usefully contain the department or work centre number in which the manufacture takes place.

51. Initiation Date.

The date (month and year) when the item was initiated.

52. Date Last Moved.

This date can be used to highlight obsolete or dead stock

53. Alpha Smoothing Constant.

Used for exponential smoothing techniques in the case where a special smoothing constant for the item is required.

54. Physical Inventory.

The count at the last physical stock - take of the item.

55. Date of Last Count.

Date inventory was taken for this item.

56. Low Level Code.

This code is a level number, associated with the product structure file and denotes the lowest level, in all products on the file, at which the item occurs.

For example in the structure illustrated in Fig. 3.2 Part C would have a low level code of 3 since this is the lowest level at which C occurs.

In the case of a random access file on a direct access device a number of address fields to related files will be required.

Examples of these address fields are:

Product structure address

Address of first routing operation

Address of gross requirements file

Outstanding orders file address.

3.5 OUTSTANDING ORDER FILE

Once an order has been placed on a supplier or on the works, this stock is considered available. All that is left is to ensure that the commodities are received in time. The outstanding order file serves the purpose of follow-up and "chasing" as well as that of indicating the "outstanding orders" component of available stock.

This file is updated by the two transactions: orders placed and goods received. It carries all the details pertaining to the particular order.

1. Item Number.

The code number of the item that has been ordered.

2. Order Number.

The unique number associated with this order and quoted to the supplier (or the works) when placing the order. The supplier in turn quotes this number when making his delivery.

3. Date.

Of the order.

4. Supplier Number.

This is the code number assigned to the supplier as referred in the inventory control master file No. 50 and corresponding to the number allocated to this supplier on the creditors file. See appendix In the case of a works order the department, work centre or even machine number can appear in this field.

5. Buyers Code.

Used if required to indicate the buyer who placed the order.

6. Delivery Date.

Date commodity is required in receiving store.

7. Quantity Ordered.

Original order quantity.

8. Quantity Outstanding.

Quantity yet to be delivered.

9. Number of Deliveries.

The number of deliveries which have thus far been made against this order for this commodity.

10. Quantity Tolerance.

This figure expressed as a precentage specifies the percentage over or under supply which is tolerable.

For example if the tolerance is specified as 5% and the original order quantity was 1000 then a delivery of 960 would yield this order complete.

11. Unit of Measure.

Corresponding to the unit code on the inventory master file No. 9. The quantity ordered must be specified in terms of this unit.

12. Price.

The price quoted to the buyer when placing the order.

13. Price Unit.

This code is used when the price is quoted in a different unit from the unit used internally.

For example if the company has already metricated and is ordering in Kilograms but the supplier still has 100 pound containers, the buyer may then specify the price in terms of lbs. and indicate this in the price unit field provided on the purchase order requisition.

3.6 RELATED FILES

The other related information files such as creditors (or suppliers), routing and work centre are not directly associated with the system here discussed. They are however logical extensions of the system and thus appear in the appendix.

CHAPTER FOUR

INPUT - COMMUNICATING WITH THE COMPUTER

The tremendous advances made in latter times in the field of data collection make this subject extensive and outside the scope of this study. However, whether the form of data collection used is the punched card, paper tape, magnetic tape or direct input via terminals, the importance of the source documents should not be under-estimated. Careful design of the man-machine interface in the system contributes much to the success of implementation.

A large volume of data collection is necessary to set up and maintain the system. Data such as orders placed, material drawn, material received and jobs completed are required on a continuous or repititious basis. Each of these data records must at some stage be handled by people. The validity of the information must, wherever possible be verified by the system. In addition the master or static files must be updated when the situation demands for example when a new product is designed or a new item is introduced into a product.

4.1 UPDATING THE PRODUCT STRUCTURE FILE

The need for updating the product structure file arises whenever an engineering change is made to a product or a new product is initiated.

The reasons for product updating ar numerous but the control of the product structure files should be in the hands of an individual or a department such as the production planning department. Updating of the product structure file is usually done using punched cards and thus preprinted card layout with fields clearly labelled are advisable.

Facilities for adding, changing and deleting records or entire assemblies should be provided for in order to give maximum flexibility and to minimise the clerical effort involved.

Standard retrievals such as single level explosions, indented parts list and "where used lists", (refer to Chapter 5), should be readily available and be kept up to date. A change to a component of one assembly may requirea change to the same component in another assembly.

After each update a listing should be produced, showing the revised version of the altered assembly. These amendments to the product structure file are circulated to the departments concerned, for example, engineering, costing and production planning.

The following audit trails done programatically are advisable:

(i) a part added should appear on the inventory control master file

(ii) the unit of measure specified on the product structure should coincide with that of the item on the master file

(iii) the parts chain must always terminate on a bought-out item i.e. a component or raw material

(iv) validity of transaction code must be checked. For example, only A-add, D-delete, C-change and R-replace may be allowable.

(v) a parent-component relationship should not be duplicated.

(vi) the relationship specified may cause "looping", for example:

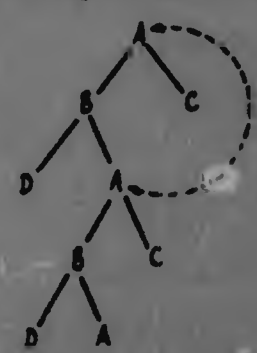


Figure 4.1

Above a loop has been caused between B and A since A is made up of B and C, while B in turn is made up of A and D. This is not possible since A consists of B

and B consists of A cannot simultaneously be true.

After updating warning can also be given such as: component now has no where-used chain. This would occur when a component is removed from all its parents and does not appear on the structure file any longer but still exists on the master.

An example of a simple input updating form is shown below:

Card Columns	Field
1	Transaction code
2-5	Date of update MMYY
7-16	Parent item number
18-27	Component item number
28-29	Component unit of issue
30-39	Quantity of components contained in parent
40-45	Effectivity date of chain
46-50	User department code

In the case of sequentially stored product structure files described in Chapter 3, the input updating form used could be:

1	Transaction code
2-5	Date of transaction
7-16	End-product item number
18-27	Assembly, component etc., item number
28-28	Assembly, component etc., unit of measure
30-31	Level number, with respect to end product final assembly
32-41	Quantity of item contained in the item one level higher

42-46 Sequence number defining uniquely the record in the product structure to be changed or deleted, or indicating the position in which it is to be added.

47-51 User department code.

4.2 UPDATING THE PRODUCTION PLAN FILE.

The production plan file is automatically updated each month. In order to maintain a fixed length planning horizon, an additional month's plan must be added each month. At the month-end the previous month's planned quantities are averaged and used for the additional month's plan.

For example, if the production plan over a planning horizon of 6 months is as follows:

January	80;	February	20;	March	70
April	40;	May	150;	June	60
	Average	420/6	= 70		

then the assumed plan for July is 70.

The plan must be able to be updated manually as required, to allow for inclusion of possible short-term programs or revisions of long-term ones. This can be done simply using punched card input specifying a change, addition or deletion to a quantity applicable to a particular time period. For example:

Column	1	2-11	12-15	16-22	23-26	......
Field	code	product code	period number	quantity	period number	

27-33	etc......	80
quantity		card number

6 periods can be catered for on each card. Any number of cards can

be used to cover the number of periods in the planning horizon.

After each update the new production plan should be printed and circulated to those concerned for verification of its validity.

4.3 UPDATING THE INVENTORY MASTER FILE.

This file contains both input and generated fields. The self updated fields have been discussed in Chapter 3, and require no further elucidation.

The documentation required for updating the variable fields, require careful consideration and planning.

1. Stores Control.

Besides the requirement for inventory control, all companies require an audited stock figure once per annum. More commonly, however, the firm requires a perpetual stock system for continuous profit evaluation and stock control.

While perpetual stock systems are generally expensive to maintain, they are vital to inventory control systems, are often by products of costing systems, save physical stocktaking and minimize pilfering.

2. Requisition for Stock.

Assuming that data captureis done "off line" then a document is required in order to signify issue of material and provide authority for stores release. It is suggested that where possible the computer produce the requisitions generated using the product structure and inventory master files. The"user department code" field suggested for the product structure file facilitates this.

Thus if all final assembly components (i.e. level 2 items in the product structure file) are coded with their assembly department number a requisition can be produced which is unique to each section of the store andto the destination department.

An example of this appears below. In order to make 100 A's, 100 B's, 200 C's, 100 D's, 500 E's and 200 F's are required.

B, C, and F. are stored in the raw material store, as indicated on the inventory control master (field No. 7 location).

D. and E, are stored in the component store. All parts are assembled in assembly department 17 with the exception of C which must first go to the plating shop, department 9, prior to assembly.

After explosion of product A. using the structure file, the components are then extended with their descriptions, and stores location codes from the inventory control master file.

The location and destination codes are then used as the major sort keys to produce three requisitions as follows:

Requisition No. 3561

Job No: 123456 Date: 14-09-70

Store: Raw Material No.2 Department: 17

Commodity No.	Description	Unit	Quantity Reqd.	Qty. Issued
B	Screw Steel BSW 3/8 x 1/4 RSD	EA	100	
F	Steel Mild Strip 3 x 3/16 x 36	EA	200	

Requisition No. 3562				
Job No: 123456			Date: 14-09-70	
Store: Raw Material No. 2			Department: 9	
Commodity Number	**Description**	**Unit**	**Quantity Required**	**Qty. Issued**
C	Steel Screw No. 6 x $1\frac{1}{2}$- RSD HD	EA	200	

Requisition No. 3563				
Product No: 123456			Date: 14-09-70	
Store: Component No. 1			Department: 17	
Commodity Number	**Description**	**Unit**	**Quantity Requd.**	**Qty. Issued**
D	Gasket Collar	EA	100	
E	Guarentee Tag	EA	400	

A further degree of sophistication in control can be introduction by updating the "quantity allocated" field on the master at the same time as the requisition is produced.

When the goods are actually drawn from the store, then the storeman fills in the quantity issued column on the requisition. The stock and quantity allocated fields are then reduced. In this way, pending usage can be taken account of in the inventory control phases.

3. Receiving of Goods into Store:

The documentation for the receipt of goods into store is extremely important, not only to the internal efficiency of the company, but to maintaining a good relationship with suppling creditors.

The generation of the goods received note is discussed fully in section 4.4.

4.4 UPDATING THE OUTSTANDING ORDER FILE.

Two basic transactions affect this file - the placement of an order and the receipt of the goods. A system using a punched card as a "turn-around" document has proved extremely successful in ensuring the accuracy and speed of updating. The system is simple and minimises clerical effort and thus minimises errors.

1. Placing the Order.

The buying department usually places an order on a supplier in accordance with a purchase requisition raised by the production planning department. Alternatively if the order is for manufacture in the works, then the works order is placed by the planning department themselves.

The purchase order may be of any design but should include the following :

Order Date, Order Number, Supplier Number, Item Number, Delivery Date, Unit, Quantity Ordered, Receiving Department No., Quantity Tolerance, Price Quoted and Price Unit Code.

In the case of a works order the two latter fields regarding price may be ommitted.

In the case of a works order the two latter fields regarding price may be ommitted.

The above information is captured on say punched cards or paper tape and loaded onto the outstanding order tape or disc file.

For each line of each order placed cards are now punched out on a peripheral card punch (commonly about 100 cards / minute) after the basic information above has been extended by a brief item description and supplier's name. The supplier's name is not necessary if his number has been chosen with the first letter being the first alphabetic letter of the supplier's name. For example:

X001 = XYZ manufacturing company limited.

Simultaneously, a unique goods received note (GRN) number is allocated to each card for identification. Samples of such goods receiving cards are illustrated in figure 4.2.

Each receiving department maintains a file of the above cards in the following sequence:

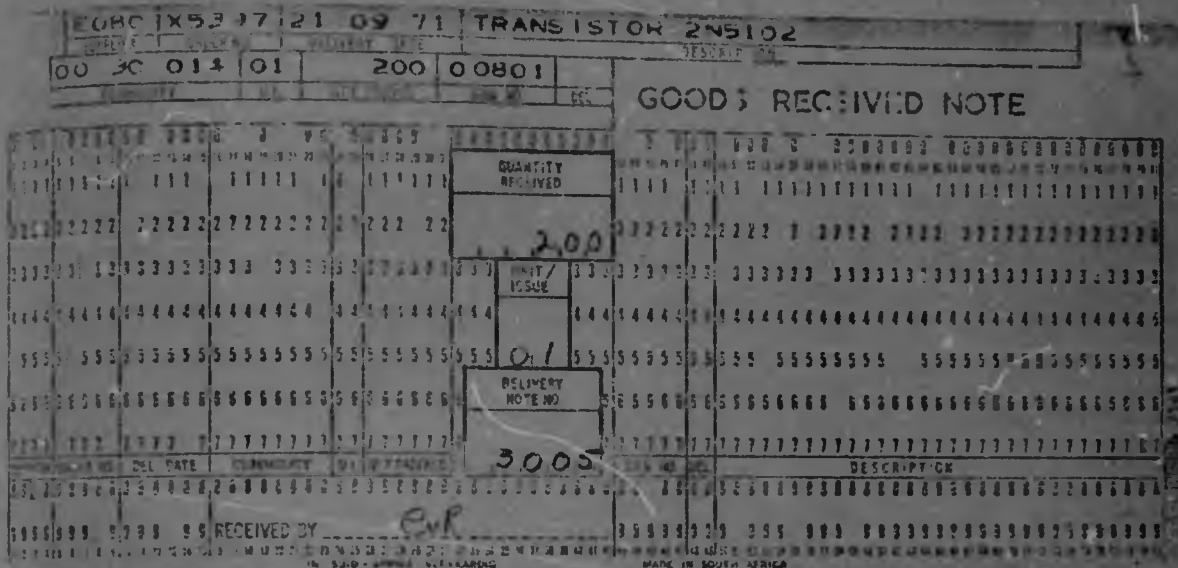
major:	Supplier Number
inter:	Order Number
Minor:	Commodity Number

The cards are conveniently stored in a card box with alphabet seperators dividing the cards into suppliers.

Works orders can be filed using the supplying department number as the major key.

When a delivery is made the suppliers name is identified from his waybill, the order number which is quoted is then selected and finally the item number or item description uniquely identifies the correct GRN card. If two or more such cards exist then the one with the earliest delivery date is used.

The variable information such as the quantity received and the suppliers delivery note, or waybill number is then entered onto the card and the card returned for processing. If the quantity received is less than the quantity ordered or outstanding, then a card is generated for the balance of the goods outstanding if this balance is greater than the quantity tolerance specified. Where no quantity tolerance is specified a standard of, say 5%, may be used.


EOBC X53?7 21 09 71 TRANSISTOR 2N5102
00 3C 014 01 200 00801
GOODS RECEIVED NOTE
QUANTITY RECEIVED
200
UNIT/ISSUE
01
DELIVERY NOTE NO
3005
DEL DATE
COMMODITY
DESCRIPTION
RECEIVED BY EvR
MADE IN SOUTH AFRICA

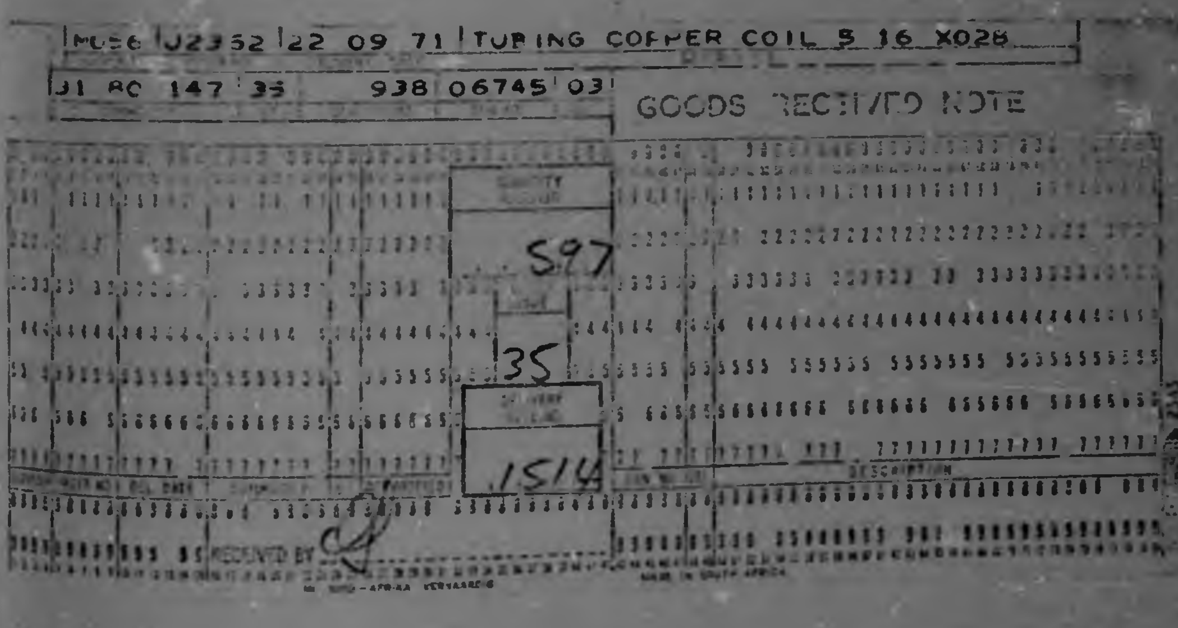

MUS6 J2352 22 09 71 TUBING COPPER COIL 5 16 X028
31 8C 147 35 938 06745 03
GOODS RECEIVED NOTE
597
35
1514
DESCRIPTION
RECEIVED BY
MADE IN SOUTH AFRICA

Figure 4.2

The parallel card file in the receiving department thus maintains the current outstanding position of all orders at any stage. The receipts each day are used to update the stock position of each item at the same time as the outstanding order file is updated.

A further by-product of the goods received note generated from the order is the clearance of creditors' accounts. The price quoted on the order is one of the fields on the outstanding order file. When a receipt is acknowledged through the turn around card the quantity received is multiplied by this rate to yield the value of the delivery. The invoice has only to be validated in terms of this value for clearance of the suppliers invoice to be initiated by printing his cheque or remittance advice.

CHAPTER FIVE

OUTPUT : COMMUNICATING WITH MAN

The system only affects the environment when it presents its information to the people who must implement it. The wealth of information contained in the files must be easily retrieved in a concise and decisive manner. The principles of management by exception can be used to great advantage in the products of reports.

Much depends on the computer facilities available. If large random access storage is available with remote enquiry terminals, information can be acquired and disseminated without printing details of all items. On the other hand where facilities are limited, careful consideration is required in optimising the use of reports.

5.1 RETRIEVALS FROM THE PRODUCT STRUCTURE FILE.

These retrievals are of great value mainly to the engineering department of the firm. They are however intimately linked to the problems of inventory control providing as they do the vital information pertaining to the component contents of each product.

a) Single Level Explosion or Assembly parts list (Figure 5.1)

The single level bill of material can be used for assembly orders, requisitions or level by level net requirements planning. (See Section 5.2).

The retrieval of the single level explosion is derived directly from the product structure which contains the parent-component link records.

S I N G L E   L E V E L   P A R T S   L I S T .

ASSEMBLY 31647 - KETTLE 4PINT COMPLETE

PART NO.	DESCRIPTION	QUANTITY	UNIT	TYPE
59-32-864	BODY ASSEMBLY - 4 PT.	1	EA	A
57-31-818	ELEMENT 2KW COMPLETE	1	EA	L
59-23-821	COLLAR - 2KW ELEMENT	1	EA	L
77-21-355	GASKET COLLAR 2KW	2	EA	L
59-23-894	HANDLE ASSEMBLY 4PT	1	EA	A
19-18-367	NUT PRESSED STEEL 1/8TH 2BA NI PLATED	2	EA	L
78-63-422	GASKETS HANDLE SMALL	2	EA	L
59-17-003	LID ASSEMBLY	1	EA	A
84-30-201	CARTON - 4PT KETTLE	1	EA	L
10-14-311	GAURENTEE TAG - KETTLES	1	EA	L
27-06-224	INSTRUCTION LEAFLET - KETTLES	1	EA	L

Figure 5.1

The descriptions, units of issue, origin or any other item details are obtained from the inventory file.

b) Indented Parts list (Figure 5.2)

This, the complete parts list of a finished product, can be used for Gross component requirements, material costing of finished products and service parts catalogues.

c) Summarised Where-Used List (Figure 5.3)

When a company manufactures a variety of products, it is common to find the same component or raw material being used in a number of these products. The summarised where-used list indicates the relationship of a commodity to its various parent products.

This report: aids greatly standardisation in design, can be used as an aid in value analysis, facilitates engineering charge notices and indicates the impact of component shortages on production schedules.

A specific benefit relevant at present is the ability to substitute metric for imperial components in all applicable products.

I N D E N T E D   P A R T S   L I S T .

ASSEMBLY 31667 - KETTLE 4PINT COMPLETE

LEVEL	PART NO.	DESCRIPTION	QUANTITY	UNIT	TYPE
1	89-32-864	BODY ASSEMBLY - 4 PT.	1	EA	A
.2	32-84-613	BODY - 4PT	1	EA	F
..3	11-01-321	STEEL SHEET 96X48 IN CRCQ 18G	0,0372	EA	L
.2	14-17-833	SPOUT	1	EA	F
..3	11-01-321	STEEL SHEET 96X48 IN CRCQ 18G	[illegible]0081	EA	L
.2	46-60-397	LEG PLASTIC 837/21	3	EA	L
.2	19-21-214	SCREW STEEL 1/4 X 3/8 RSD HD NI PLTD.	3	EA	L
1	67-31-818	ELEMENT 2KW COMPLETE	1	EA	L
1	49-23-821	COLLAR - 2KW ELEMENT	1	EA	L
1	77-21-355	GASKET COLLAR 2KW	2	EA	L
1	89-23-894	HANDLE ASSEMBLY 4PT	1	EA	A
.2	17-81-311	HANDLE GUIDE 4PT	2	EA	F
..3	35-31-808	MILD STEEL WIRE 6G PLATING QUALITY	0,1730	KG	L
.2	70-17-866	HANDLE RUBBER	1	EA	L
1	19-18-367	NUT PRESSED STEEL 1/8TH 2BA NI PLATED	2	EA	L
1	79-64-822	GASKET HANDLE SMALL	2	EA	L
1	89-17-003	LID ASSEMBLY - 4 PT	1	EA	A
.2	42-63-811	LID 4PT	1	EA	F
..3	11-01-321	STEEL SHEET 96X48 IN CRCQ 18G	0,0114	EA	L
.2	70-17-463	KNOB LID	1	EA	L
.2	19-56-121	SCREW STEEL CSK HD 1/4 X 2BA	1	EA	L
1	84-30-201	CARTON - 4PT KETTLE	1	EA	L
1	10-14-311	GAURENTEE TAG - KETTLES	1	EA	L
1	27-06-224	INSTRUCTION LEAFLET-KETTLES	1	EA	L

Figure 5.2

WHERE USED LIST

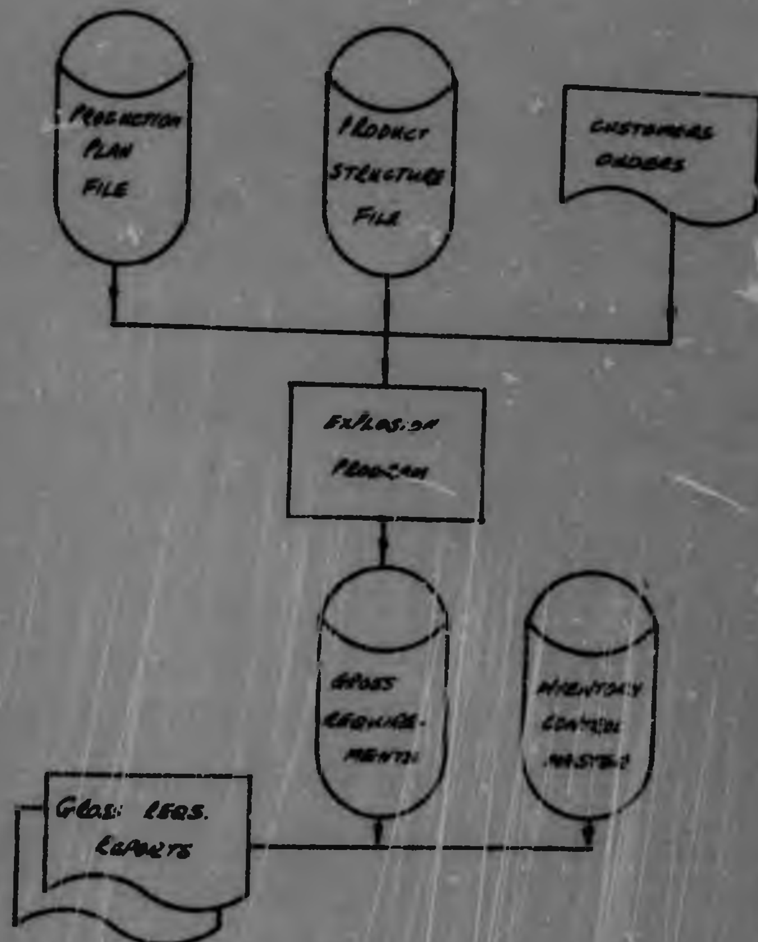
PART : 19-56-121 SCREW STEEL CSK HD 1/4 x 2BA UNIT: EA TYPE: L

ASSEMBLY NO.	DESCRIPTION	QUANTITY PER
30416	KETTLE 2PINT COMPLETE	1
30429	KETTLE 3PINT COMPLETE	1
31647	KETTLE 4PINT COMPLETE	1
32660	KETTLE 6PINT COMPLETE	1
40645	TEA POT 1PINT COMPLETE	1
41133	TEA POT 2PINT COMPLETE	1
42260	TEA POT 3PINT COMPLETE	1
43798	TEA POT 4PINT COMPLETE	1
52761	IRON 1.5KW BAKELITE HANDLE	3
52762	IRON 1.5KW PLASTIC HANDLE	3
62618	TOASTER POP-UP	2
71143	SEWING MACHINE MODEL 713C11/22	8

Figure 5.3

5.2 GROSS REQUIREMENTS GENERATION.

The first step towards solving the inventory problem in the manufacturing industry is the generation of the requirements for the various assemblies, sub assemblies, components and raw materials to manufacture the end products desired.



The gross requirements file is generated as described in section 3.3.

A number of vital reports can be generated from the gross requirements file in conjunction with the item master file.

By sorting the purchased parts' requirements into supplier (field 50 of the inventory master) sequence, each supplier's anticipated orders for say a year can be projected. (Refer Figure 5.4). This enables annual contract orders to be placed on which release orders can be issued month by month in accordance with net requirements generated (See Section 5.3). The advantages of such purchasing procedures are many.

1) Optimum and constant prices can be obtained.
2) Financial planning with respect to costs of raw materials can be accurately done.
3) Negotiations are entered into only once per annum.
4) Prior warning to suppliers usually leads to improved delivery since the supplier will batch his production in order to meet his customer's year's requirements. In the case of certain manufactured components the supplier will often choose to manufacture the firm's total requirement for the year in one production run. The supplier thus carries the stock on behalf of the firm for this advantage.

It is advisable that latitudes be allowed in the quantity specified in the contract to cater for alterations in program.

It is not uncommon to find that firms are able to save 10% or more on the costs of purchased commodities using the above method.

The implementation of such a procedure is relatively simple using the computer. A standard letter can be generated by the computer proposing a contract order, with the projected quantities and commodities listed.

G R O S S   R E Q U I R E M E N T S   F O R   T H E   P E R I O D   M A R C H   1971   T O   F E B . 197[illegible]

SUPPLIER NO. X372 - XYZ MANUFACTURING CO. (PTY) LTD

[illegible]EM #	D E S C R I P T I O N .	*	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	[illegible]
[illegible]3076	SPACER NEOPRENE	2	2000	1500	300	0	3500	2000	1000	2500	3000	500	500	[illegible]
18110	CLAMP PLASTIC C14/38		4000	6000	3000	1000	5000	0	500	7000	2000	1000	3000	[illegible]
18319	CLAMP PLASTIC C14/37		200	300	150	50	250	0	10	350	10[illegible]	50	150	[illegible]
44397	LEG PLASTIC B37/21		2000	1500	300	0	3500	2000	1000	2500	3000	500	500	[illegible]
34002	GROMMET RUBBER B14/33		10000	17000	32000	40000	[illegible]1000	25000	9000	34000	14000	10000	8000	[illegible]
17463	HANDLE RUBBER	1	500	400	100	0	900	500	300	600	750	120	160	[illegible]
17[illegible]66	KNOB LID	1	3000	2000	500	100	4500	3100	1800	3000	4000	700	800	[illegible]

[illegible]TERNATIVE SUPPLIERS 1=G329 2=P860

Figure 5.4

In larger companies it is common to have the function of production planning split among a number of people (field 48 of the inventory file - planner's code).

It is extremely useful for each planner to have for ready reference a list of the gross requirements for the year of the items under his control.

5.3 NET REQUIREMENTS GENERATION.

The generation of the "net requirements" i.e. the requirements of the plant to meet its production plan, is the cornerstone of the entire system. Basically the net requirements may be defined as forecast and/or production program requirements (gross requirements) less available inventory quantity. The net requirements are thus the quantity to be produced or purchased.

Deriving the net requirements is complicated by the fact that assemblies and components are usually stocked at various levels.

For example, in the case of the kettle whose parts list is illustrated in Figure 5.2, if the manufacturing program called for 500 4 pint kettles during January, then 500 lid assemblies (Assy No. 8917003) would be required to meet this program. In turn, therefore 500 knobs (Part No. 70.17.463) are required.

If however the Lid Assemblies (89.17.003) are kept in a work-in-process store then the net requirement of Lid assemblies for the month of January will be reduced by the available stock at the beginning of that period.

For example if the available stock of lid assemblies was 200, then a net requirement of 300 is generated. Thus, in turn the gross requirements for Knobs (70.17.463) is reduced to 300. If the available stock of knobs is 400 then no net requirement for knobs exists for January. There are thus "hidden stocks" of knobs within the knob assemblies which therefore must be accounted for, before orders can be leased.

The lead time for the procurement, assembly or manufacture of each item must now be used to time the release of orders.

The following two simple hypothetical structures will serve to illustrate the entire netting procedure.

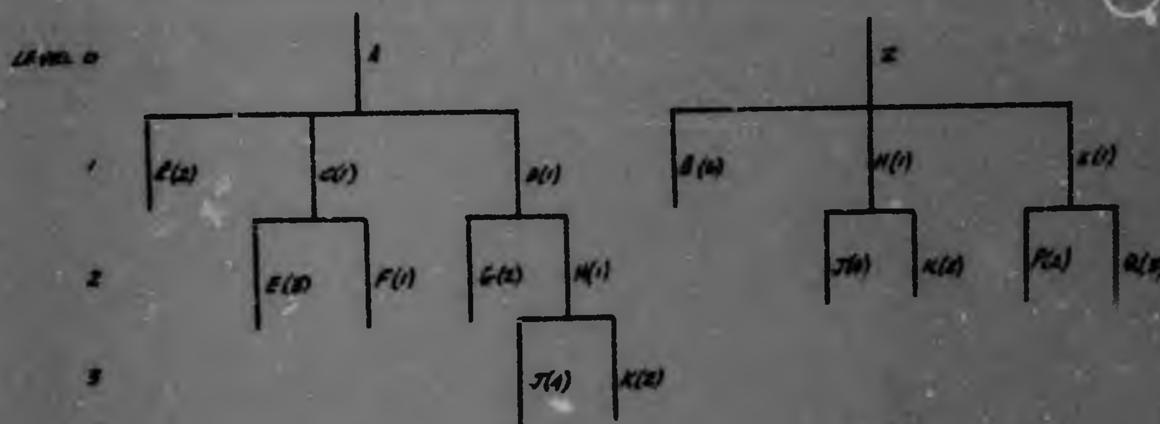


Figure 5.5

The figures in parentheses indicate the quantity of the component related to it's parent.
The requirements for A and Z according to the production plan are as follows:

Period	4	5	6	7	8
A	100	0	200	100	0
Z	50	50	50	50	50

The lead times are as follows:

To assemble A, Z, D & H	- 1 period each
To procure B & Q	- 2 periods each
To assemble C	- NIL (for practical purposes)
To procure E,F,G,P,J & K	- 1 period each
To assemble X	- 2 periods

The available inventories at the beginning of the requirement periods are as follows:

A	NIL
Z	NIL
B	600
C	200
D	200
E	100
F	NIL
G	NIL
H	200
J	NIL
K	100
X	100
P	NIL
Q	200

A and Z are end items which are required in accordance with the production program. It is assumed that the planned quantities have been calculated taking account of set-up, run times, forecasted sales and storage costs.

In order to make 100 A's in period 5, the product structure must be exploded at the first level to determine the requirements for assembly. Since the lead time for assembly of end-product A is one period, the components and sub-assemblies of A, namely B, C and D are required one period earlier i.e. in period 4.

Having exploded A and Z in this way, the gross requirements for B, C, D, X and H are calculated. The requirements of B must be consolidated since they are required to make both A and Z. At this stage the low-level code (inventory control file - field 56) must be checked. H has a low-level code of 2 since it appears on A at level 2. No order can be planned at this stage, until explosion of the planned orders at level 1 is complete. Orders may now be planned for B, C, D and X since none of these appear on any lower level in the product structure file.

The net requirements for B, C, D and X can be calculated by deducting the available stock. From these net requirements, a planned order can be calculated in accordance with the order policy specified on the inventory master file (field No. 34) e.g. EOQ, least unit cost etc and the order quantity modifiers, fields 35-40.

The planned orders must now be offset by their assembly or procurement lead times. For example, the planned order for D is 200 in period 6, therefore the parts required to make 200 D's, viz. 400 G's and 200 H's must be available in period 5.

When the explosion of the level one planned orders has been accomplished, the low-level code is again checked;if this code is now equal to 2 orders may again be planned. Thus total gross requirements for H may be calculated. They are:

50 per period due t

and 200 in peroid 5 due to the planned order of D.

The entire procedure is continued until all levels have been exploded and all orders planned. The details of the entire netting procedure are illustrated in Figures 5.6, 5.7, and 5.8.

The planned orders can now be written to a file of planned orders containing the item number., period and quantity to be released. Only items with a requirements policy code of 2 (see inventory control master file, field 3) will be included in the file.

From the planned order file, purchase requisitions can be printed and works orders can be released.

Purchase Order Requisitions.

The planned orders can be sorted into "make" and "buy" items according to the item type code on the master. All the "buy" item requirements must be released to the planning office for approval prior to orders being placed. It is advisable to have manual intervention at this stage of the system. The reason for this is the fact that so many variables exist in the provisioning of components and raw materials, that rigid application of computer reports may overlook intangible factors familiar only to the person controlling inventories. Reference can be made to the net requirements generation print-out where gross requirements, available stocks, lead times and order policies may be verified.

The report in Figure 5.9 is designed to accumulate the planned orders for each supplier.

N E T   R E Q U I R E M E N T S   G E N E R A T I O N   F O R   P E R I O D S   1 TO 8   PG.1

COMMODITY:A   STOCK ON HAND: NIL   LEAD TIME: 1 PERIODS   ORDER POLICY:

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE				100	0	260	100	0
NET REQUIRE				100	0	200	100	0
PLANNED ORDER				100	0	200	100	0
ORDER OFFSET			100	0	200	100	0	

COMMODITY:X   STOCK ON HAND: NIL   LEAD TIME: 1 PERIODS   ORDER POLICY:

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE				50	50	50	50	50
NET REQUIRE				50	50	50	50	50
PLANNED ORDER				50	50	50	50	50
ORDER OFFSET			50	50	50	50	50	

COMMODITY:B   STOCK ON HAND: 600   LEAD TIME: 2 PERIODS   ORDER POLICY: 3

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			500	300	700	500	300	
NET REQUIRE			0	200	700	500	300	
PLANNED ORDER				900		800		
ORDER OFFSET		900		800				

COMMODITY:C   STOCK ON HAND: 200   LEAD TIME: NIL   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			100	0	200	100	0	
NET REQUIRE					100	100		
PLANNED ORDER					200			
ORDER OFFSET					200			

COMMODITY:D   STOCK ON HAND: 200   LEAD TIME: 1 PERIODS   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			100	0	200	100	0	
NET REQUIRE					100	100		
PLANNED ORDER					200			
ORDER OFFSET				200				

Figure 5.6

N E T   R E Q U I R E M E N T S   G E N E R A T I O N   F O R   P E R I O D S   1 TO 8   PG.2

COMMODITY:X   STOCK ON HAND: 100   LEAD TIME: 2 PERIODS   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
OSS REQUIRE			50	50	50	50	50	
ET REQUIRE					50	50	50	
ANNED ORDER					150			
DER OFFSET			150					

COMMODITY:E   STOCK ON HAND: 100   LEAD TIME: 1 PERIODS   ORDER POLICY: 3

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
OSS REQUIRE					600			
ET REQUIRE					500			
ANNED ORDER					500			
DER OFFSET				500				

COMMODITY:F   STOCK ON HAND: NIL   LEAD TIME: 1 PERIODS   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
OSS REQUIRE					200			
ET REQUIRE					200			
ANNED ORDER					200			
DER OFFSET				200				

COMMODITY:G   STOCK ON HAND: 200   LEAD TIME: 1 PERIODS   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
OSS REQUIRE				400				
ET REQUIRE				200				
ANNED ORDER				200				
DER OFFSET			200					

COMMODITY:H   STOCK ON HAND: 200   LEAD TIME: 1 PERIODS   ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
OSS REQUIRE			50	250	50	50	50	
ET REQUIRE				100	50	50	50	
ANNED ORDER				250				
DER OFFSET			250					

Figure 5.7

NET REQUIREMENTS GENERATION FOR PERIODS 1 TO 8 PG.3

COMMODITY:J STOCK ON HAND: NIL LEAD TIME: 1 PERIODS ORDER POLICY: 3

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			1000					
NET REQUIRE			1000					
PLANNED ORDER			1000					
ORDER OFFSET		1000						

COMMODITY:K STOCK ON HAND: 100 LEAD TIME: 1 PERIODS ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			500					
NET REQUIRE			400					
PLANNED ORDER			400					
ORDER OFFSET		400						

COMMODITY:P STOCK ON HAND: NIL LEAD TIME: 1 PERIODS ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			300					
NET REQUIRE			300					
PLANNED ORDER			300					
ORDER OFFSET		300						

COMMODITY:R STOCK ON HAND: 200 LEAD TIME: 2 PERIODS ORDER POLICY: 4

PERIOD	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
GROSS REQUIRE			450					
NET REQUIRE			250					
PLANNED ORDER			250					
ORDER OFFSET	250							

Figure 5.8

PLANNED PURCHASE ORDERS FOR THE PERIOD 1 TO 6

PLANNER 01

SUPP#	ITEM #	DESCRIPTION	LEAD TIME	QNTY REQUIRED-PERIOD -1-	-2-	-3-	-4-	-5-	-6-	PREV. PRICE	STD. PRICE	UNIT	**
A302	372043	CYLINDER HEAD CASTING	2	100	0	40	150	0	0	0.86	0.80	EA	1
A302	592100	MOTOR HOUSING CASTING	4	20	30	100	50	50	0	1.32	1.33	EA	
A302	996017	SLEEVE	1	80	60	0	0	100	70	0.43	0.43	EA	2
C116	101173	GOLD WIRE GRADE X33	2	1000	300	500	2000	0	1000	0.17	0.16	M	
C116	420661	GOLD WIRE GRADE X39	2	200	200	0	0	200	100	0.21	0.21	M	
D00[illegible]	273146	SOCKET P3114	1							0.73	0.80	EA	
M193	103042	SWITCH DOUBLE POLE 5A	1	70	80	30	10	0	50	0.14	0.14	EA	3
M193	195267	RELAY 220V - E3819	2	10	5	12	0	15	4	0.29	0.30	EA	4
M193	360369	SWITCH F3796	1	100	0	0	0	0	0	0.55	0.56	EA	3
M193	511875	CONTACTOR G1192	1	20	0	10	10	0	0	1.23	1.23	EA	
M193	727431	GENERATOR 0.5KW X116	3	1	0	0	2	0	2	14.76	14.55	EA	
M193	948109	TRANSFORMER 2CVA	2	30	30	30	30	30	30	2.62	2.60	EA	5
H934	806641	BRASS ROD 3/8 DIA	3	90	20	30	40	50	10	0.23	0.23	KG	6
H934	806679	BRASS ROD 9/16 DIA	3	40	70	60	20	60	40	0.24	0.23	KG	6
K220	176302	SPRING PHOSPHOR BRONZE	1	320	440	200	260	310	200	0.02	0.02	EA	
K466	201328	ALUM. EXTRUSION D1173	1	10	12	12	8	9	10	0.63	0.63	EA	
K466	469408	ALUM. EXTRUSION D2324	1	20	30	35	25	20	15	0.91	0.90	EA	

** ALTERNATIVE SUPPLIERS 1=P321 2=S116 3=J006 4=M211 5=Q032 6=G301

Figure 5.9

Negotiations are greatly facilitated by this accumulation since release orders can be issued against the contract orders referred to in section 5.2. The supplier number printed is the most popular supplier in terms of recent purchasing history. Alternative suppliers are indicated to enable competitive prices to be obtained in the case where no contract has been entered into.

In the cases where suppliers are in possesion of dies made specifically for the firms requirements, contracts are relatively common.

The flexibility of the planned purchase order schedule is great due to the fact that periodic requirements generations can be made in order to adapt to changes in production program, component changes and varying usage rates. Firm release orders need only be given to suppliers approximately one lead time prior to the required date in order that changes may be introduced into the planned purchase orders schedule with minimum disruption of suppliers own production schedules. However an indication of future requirements will aid the manufacturing supplier to improve his scheduling and thus his delivery.

Works Order Release.

The works order schedule is vital to the successful planning and control of the production environment. Using the schedule, labour and machine requirements can be evaluated and corrective action taken where necessary. The level by level net requirements generation as illustrated in this section ensures that each part is available for assembly at the next level at the right time and in the correct quantity to meet the required date of the end products. After the production planning department has perused the schedule, they may be released to the respective department foremen. This procedure enables each department head to do his own forward planning in co-ordination with the planning department.

With the aid of a routing file (See Appendix 5) capacity planning and scheduling may be done on the computer as an extension to the inventory control system.

The works order schedule is very similar to that of the purchase order schedule and is illustrated in Figure 5.10. The set-up and run times are derived from the routing file. Departments 22 and 49 as shown have only sample loads. In the case of the works order schedule, the requirements are offset by the lead time in order that the start times are indicated to the production departments.

The retrievals illustrated in Figures 5.9 and 5.10 are samples of the type of report available from the planned orders file. The individual requirements of the firm will direct the exact format and/or sequence of such reports.

5.4 CONTROL OF NON DEMAND-DEPENDENT ITEMS.

The preceding two sections illustrate a suggested control procedure for both "make" and "buy" items. However the generation of the requirements for such items presumes two factors:

(i) All the products of which the item is a part, have a standard structure coded on the product-structure file.

(ii) All the products of which the item is a part appear on a rigid production plan.

In the case of special made-to-order products the above two requirements will not be fulfilled.

In addition a great number of items cannot suitably be controlled as suggested in the preceding two sections. These types of items,

P L A N N E D   W O R K S   O R D E R S   F O R   T H E   P E R I O D   1 T O 3

P L A N N E R : 01

DEPT NO.	ITEM#	D E S C R I P T I O N	SET-UP TIME(H)	1 QUNTY	1 TIME(H)	2 QUNTY	2 TIME(H)	3 QUNTY	3 TIME(H)
14	30416	KETTLE 2PT ASSY COMPL.	0,5	100	32	100	32	0	0
14	30429	KETTLE 3PT ASSY COMPL.	0,6	0	0	0	0	50	16
14	31647	KETTLE 4PT ASSY COMPL.	0,0	500	126	500	126	500	126
14	32660	KETTLE 6PT ASSY COMPL.	1,0	50	17	50	17	0	0
14	52761	IRON 1.5KW BAR.HANDLE	0,0	100	15	200	30	100	15
14	52762	IRON 1.5KW PLASTIC HAND	2,0	50	8	0	0	50	8
14	53060	IRON 2KW BAKELITE HAND.	0,0	200	30	100	15	200	30
14	53961	IRON 2KW PLASTIC HANDLE	2,0	0	0	0	0	10	2
14	62614	TOASTER POP-UP.	2,0	10	5	10	5	10	5
14	79061	TOASTER CONVENTIONAL	2,0	0	0	0	0	5	3
TOTALS DEPT. 14					233 HOURS		225 HOURS		205 HOURS
22	3284613	BODY -4PT KETTLE	3,0	2000	20	0	0	0	0
22	3649701	BODY -6PT KETTLE	3,0	0	0	500	7	0	[illegible]
22	4130416	BODY -2PT KETTLE	3,0	1500	15	0	0	0	0
22	4932660	BODY -3PT KETTLE	3,0	0	0	0	0	500	7
22	5263811	LID -4PT KETTLE	2,0	0	0	2500	20	0	0
22	5328119	LID -6PT KETTLE	2,0	0	0	0	0	1000	9
TOTALS DEPT. 22					35 HOURS		27 HOURS		16 HOURS
49	1902616	LID ASSEMBLY 4PT	0,0	1000	10	0	0	500	5
49	5020196	LID ASSEMBLY 6PT	0,2	100	1	100	1	100	1
49	7703418	BASE ASSY 1.5KW IRON	0,0	200	50	200	50	200	50
TOTALS DEPT. 49					61 HOURS		51 HOURS		56 HOURS

Figure 5.10

as described in field 4 of the inventory control master file, are best controlled using conventional methods of forecast demand from past data and order point theory.

The procedure which can be instigated, is to handle those items with "requirements policy code" of 1 (field 4 of the master) in the manner suggested above as apart from those with codes of 2 for which net requirements generation is most suitable.

The conventional order point method of control depends on the simple decision rule:

Order point = (Average demand x Lead time) + Safety Stock

When the available stock, namely:

Stock on hand + Order outstanding - Quantity allocated

falls below the order point, then an order is generated.

The basic difference between this method of control and that of the net requirements generation method is that in the latter case orders are planned in advance and thus do not necessarily require perpetual stock records. In the case of the order point method, stock and outstanding order levels must be updated as regularly as possible. Depending on the nature of the production of the firm, this could vary between once per day, and once per week.

Ideally instantaneous updating of the information files at the time of the transaction taking place is desired. In such an environment an order may be generated as soon as the available stock drops below the order point. This level of sophistication can seldom be economically justified due to the fact that large on-line information storage facilities are required.

It is usually found satisfactory to update the activities of the day during the evening data-processing shift. The reports produced can include the items moved during the day, with an exception report

RE - ORDER REPORT 55 AT 31-06-71

PLANNER 91

ITEM #	DESCRIPTION.	LEAD TIME	UN	STOCK ON HAND	O/S ORDERS	AVE. DEMAND	AVE. TREND	SAFETY STOCK	ORDER QUANTY	SUPPLIERS
2192321	SCREW STL.HSW 3/8X1/4 RSD	3W	EA	39624	20000	40200	1200	32000	100000	H261,N031
2293781	WELDING ROD 126 30621	2W	EA	16	0	20	1-	13	25	A822,W605
3306600	POP RIVET 1/8 STL HUSH HD	1W	EA	4250	0	2257	123-	3000	6500	A762,P114
3762150	OIL SAE 40	2W	LT	52	0	43	0	35	70	W625,S133
3999132	3-CORE CABLE 7/.064	3W	M	186	300	310	3	200	600	K195,R996
3440362	DRILL HSSS 1/8 TH	2W	EA	76	0	65	2	45	200	T016,W337
5440363	DRILL HSTS 3/8 TH	3W	EA	4	0	14	1-	6	30	T016,W337
5521100	FILE TRIANGULAR 8 SMOOTH	4W	EA	6	0	8	0	4	20	C844,W887
5596211	TAP BSW 5/16TH	3W	EA	3	0	5	0	3	15	T016,W337
5608814	ROD BRAZING 1/8TH	5W	KG	77	0	56	2	44	90	D885,J101
5608816	ROD BRAZING 3/16TH	5W	KG	51	0	21	0	35	40	D885,J101
5681422	SOLDER IRON 32 OZS	2W	EA	5	0	6	0	3	5	S195,T223
6012677	ACID PHOSPHORIC	2W	LT	203	0	153	11-	127	250	E090,G604
6211314	TRICHLORETHYLENE	6W	LT	106	0	70	0	42	100	F702,L073
7329623	PAINT WHITE ACRYLIC	1W	LT	93	0	107	13	52	220	C265,W402

PLANNER 02

ITEM #	DESCRIPTION.	LEAD TIME	UN	STOCK ON HAND	O/S ORDERS	AVE. DEMAND	AVE TREND	SAFETY STOCK	ORDER QUANTY	SUPPLIERS
1920393	LAMPS 220V 60W BC CLEAR	2W	EA	322	0	466	32-	320	650	K195,R996
2361811	T-PIECE CONDUIT 3/4	5W	EA	63	0	41	0	23	80	K195,P319

Figure 5.11

provided indicating those items which must be ordered. A sample of this report is shown in Figure 5.11.

Sufficient information should be provided on the report to enable the re-order decision generated by the computer to be verified in terms of the validity of stock on hand values and other variable factors. Once planning personnel have authorised the orders on the re-order report, the buying department are provided with the additional supplier and price information which enable orders to be placed without further reference to any additional data.

The control procedure described above relies on the ability of the moving average to accurately track the usage. The asterisk on the right hand side of the recorder report indicates that the moving average is"out of control". A measure of the ability of the moving average to track the actual demand is given by the field "sum of deviations" (field 24 of the inventory control master). This field accumulates the deviations from the actual demand of the forecast demand. If the forecast (or moving average) is consistently greater, or less, than the actual demand, then the "sum of deviations" will continue to increase, or decrease. Ideally the accumulated deviation should be approximately zero, since the positive deviation should cancel out the negative deviations. The sum of deviations must be measured in terms of the variability of the demand, namely the mean absolute deviation (MAD). It is to be expected that if the MAD is large the sum of deviations will at times be large. A commonly used indication of an "out of control" moving average is the ratio of sum of deviations to the MAD. If this figure of merit exceeds 5, then the moving average is considered to be "out of control" and an asterisk is printed as an indicator.

Inventory Status Report.

The reorder report only indicates those items whose available stock has fallen below their order points. As such it is an exception report. It is advisable to review all items under requirement policy 1, in terms of their status. This report, a sample of which is shown in figure 5.12, enables the planner to examine all items under his control. The items have been sorted by turnover category and planner number.

This stratification enables the controller's attention to be focused on the high value, fast-moving items.

The critical ratio, as defined in field 49 of the master file, gives an indication of how long the available stock will last before the reorder point will be reached. This figure of merit enables over- and understocked items to be readily identified. If the review period of the reorder report is fairly long, the status reports will indicate which orders should be released, prior to the reorder report being generated.

If the facilities are available, it is desirable for the reorder report to be run daily, and the status report possibly monthly, depending on the nature of the business. In this way the principles of management can be practiced by exception, since only items which must be ordered immediatly appear on the reorder report.

Identifying Excess, Obsolete or Slow-moving Items.

The disposal of excess stocks constitute an integral part of the inventory control procedure. Excess, obsolete or slow-moving stocks represent unproductive capital, a luxury few companies can afford.

Demand-dependent items which become obsolete through design

INVENTORY STATUS REPORT AS AT JANUARY 197[illegible]

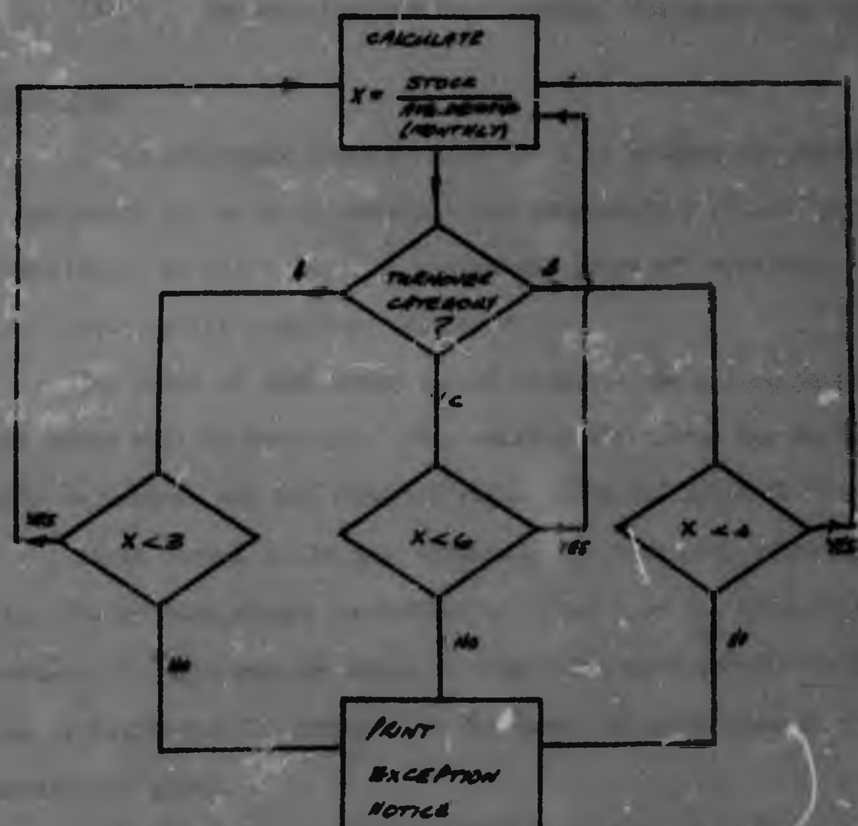
PLANNER 01

T/O CAT	ITEM #	DESCRIPTION.	LEAD TIME	UN	STOCK ON HAND	O/S ORDERS	AVE DEMAND	AVE TREND	SAFETY STOCK	ORDER QTY.	CRITIC. RATIO
A	1846[illegible]13	BUSHES GALV 1.25X0.50	3W	EA	183	200	422	14-	102		0,23
A	2192321	SCREW STL BSW 3/8X1/4 WSD	3W	EA	39628	20000	40200	1200	32000	100000	
A	3151374	SCREW STL BSW 5/16X1 CH.HD	6W	EA	24023	0	3261	327-	2050		6,17
A	5529354	BLADE HACKSAW 12X0.50X32TPI	3W	EA	537	0	132	2-	52		2,26
A	6012677	ACID PHOSPHORIC	2W	LT	203	0	153	11-	127	250	
B	1245256	BRASS ROD F.C. 5/8 DIA	6W	KG	622	350	257	18	62		2,63
B	2293781	WELDING ROD 12G 30621	2W	EA	16	0	20	1-	13	25	
B	2614587	ANGLE IRON 1X1X1/4	3W	KG	320	0	120	16-	52		1,34
B	3440362	DRILL HSSS 1/8TH	2W	EA	76	0	65	2	45	200	
B	4190718	CAUSTIC SODA	1W	KG	55	100	102	14	35		0,[illegible]
B	5169732	THINNERS 845-C01	2W	LT	216	200	327	22-	102		2,30
B	5608614	ROD BRAZING 1/8TH	5W	KG	77	0	56	2	44	90	
B	7329623	PAINT WHITE ACRYLIC	1W	LT	93	0	167	13-	52	220	
B	9008801	FIBRE WASHER TAP 1/2	6W	EA	720	0	202	5	188		1,58
C	1052609	WIRE NICHROME 20G	2W	KG	806	500	306	10	300		2,31
C	1599432	WIRE NICHROME 19G	2W	KG	327	0	86	13-	96		0,63
C	2343318	COPPER TUBING 5/1600 ,030	3W	KG	179	0	14	5-	36		7,32
C	3306600	POP RIVET 1/8 STL MUSH HD	1W	EA	4250	0	2257	123-	3000	6500	
C	3412619	ST STL ROD 3/16 DIA T304	6W	KG	44	0	5	0	7		1,L0
C	3762150	OIL SAE 40	2W	LT	52	0	43	0	35	70	
C	3999332	3-CORE CABLE 7/.064	3W	M	184	300	310	3	200	400	
C	5368778	STEEL MILD FLAT 3X3/16	2W	KG	93	0	18	0	27		1,67
C	5440363	DRILL HSTS 3/8 TH	3W	EA	4	0	14	1-	6	30	
C	5521100	FILE TRIANGULAR 8 SMOOTH	4W	EA	6	0	8	0	4	25	
C	5594211	TAP BSW 5/16TH	3W	EA	3	0	5	0	3	15	
C	5599007	STEEL SH GALV 96X48X18G	2W	EA	16	10	7	1-	4		1,13
C	5608816	ROD BRAZING 3/16TH	5W	KG	51	0	21	0	35	40	
C	5641822	SOLDER IRON 32 OZS	2W	EA	5	0	6	0	3	3	
C	6018706	SPRINGWASHER ST STL 2MM	3W	EA	620	2000	1252	27	826		0,67
C	6211314	TRICHLORETHYLENE	6W	LT	100	0	70	0	62	100	
C	7814226	PERSPEX ROD 40MM	2W	M	23	0	6	0	8		0,50

Figure 5.12

are best handled at the time of redesign. Such items should be "phased out" over a period of time.

Excess non demand-dependent items are easily identified by comparing the stock-on-hand with the usage of such items. Stock-on-hand values can be expressed in terms of the number of months of average usage. Stocks of high turnover and high value items, namely, A items, should be kept as low as possible. Thus A items are considered excess at a lower "number of months supply" than B or C items. An example of the type of decision rule which can be used is as follows:



Obsolete stocks can be identified from the "date last moved" field number 52 on the master. Each month a report indicating items which have not moved for six months can be highlighted in an obsolete stock report. Examples of excess and obsolete stock reports are illustrated in Figure 5.13.

5.5 RETRIEVALS FROM THE OUTSTANDING ORDER FILE.

The file containing details of all works and purchase orders outstanding can be usefully employed in:

(i) Budgeting for purchased requirements

(ii) Expediting late deliveries.

(iii) Reconciling outstanding order positions with suppliers.

Budgeting.

It is extremely important for the firm to know its financial commitments in terms of materials and components purchased from suppliers. As new orders are placed and goods are received, the cash required for creditors change.

The value of each order is allocated to the period in which the goods will be received. This can be derived from the delivery date requested, and the standard value or quoted price of the item.

It is useful to further subdivide the financial commitments into the product groups as defined in field 5 of the inventory master. In this way the value of orders for each product group can be realistically compared to the level of production of that particular group.

Using the principle of the turn around goods received note system described in section 4.4, the budget can be updated and the value of goods received illustrated on a daily basis. Figure 5.14 illustrates the type of budget report suggested.

E X C E S S & O B S O L E T E S T O C K R E P O R T - J U L Y 1 9 7 1

PLANNER 03 - EXCESS STOCKS

T/O CAT	ITEM #	D E S C R I P T I O N .	STOCK ON HAND	AVERAGE DEMAND	AVERAGE TREND.	NO.OF MTHS SURPLY.	UN
A	1031323	TERMINAL BLOCK 12-WAY 13A	2627	604	19	4.3	EA
A	3061454	WASHER BRASS CUP NO.6	321000	62020	1210-	5.3	EA
B	3022135	SPLIT PIN STEEL 1/16X1/2	18277	2926	54	6.2	EA
B	5359546	TOLUOL	322	76	2-	[illegible].2	LT
B	8466627	WAX PARRAFIN	183	42	1	4.4	KG
C	2115679	BRUSHES PAINT PINCH	23	2	0	11.5	EA
C	2010852	TAPE MASKING 21n	49	8	1-	6.1	EA
C	3639170	SCREW ALLEN 8BAX1IN	314	59	3	7.0	EA
C	6287791	NITRIC ACID	36	5	0	7.2	LT
C	7393348	GLOVES RED PVC 601	19	2	0	9.0	PR

PLANNER 03 - OBSOLETE STOCKS

ITEM #	D E S C R I P T I O N .	STOCK ON HAND	RATE	VALUE	DATE LAST MOVED.	UN
1455360	MITTS LEATHER	10	0.96	9.60	SEP.70	PR
2132818	KETTLE ELEMENT 2KW AX21	73	0.81	59.13	JUN.70	EA
2392259	GASKET HANDLE	3126	0.01	31.26	SEP.70	EA
3973017	BOOKLET INSTRUCTION	319	0.34	108.50	AUG.69	EA
5042610	STICKER - WARNING	8127	0.01	81.27	NOV.70	EA
7531495	HANDLE RUBBER	23	0.20	4.60	JAN.70	EA
8462866	LATCH NO.65	373	0.42	156.56	JUN.69	EA
8737578	CATCH NO.65	373	0.26	96.90	JUL.69	EA

Figure 5.13

P U R C H A S I N G   B U D G E T   A S   A T   10-06-71

PROD GRP.	P E R I O D S 06-71	07-71	08-71	09-71	10-71	11-71	12-71+	TOTAL	R E C E I P T S CURRENT	MONTH-TO-D[illegible]
01	1463	1622	1440	1426	920	0	0	[illegible]777	46	465
02	536	642	480	442	123	47	0	2270	0	[illegible]
03	4262	5326	4390	3250	2261	1012	537	21538	253	136[illegible]
04	0	0	0	126	83	0	0	209	0	0
05	287	406	314	287	260	0	0	155[illegible]	14	261
06	0	0	0	0	0	0	0	0	0	0
07	2614	2273	2006	1[illegible]1	1019	526	236	10295	0	40
08	826	809	742	95	0	0	0	2472	0	87
09	438	351	375	202	200	53	0	1719	61	129
10	1036	1218	842	362	0	0	0	3458	102	470
11	103	194	117	82	42	40	0	578	0	83
12	763	813	532	349	102	94	0	2653	31	182
13	0	0	0	0	0	0	0	0	0	0
14	156	83	0	0	0	0	0	239	0	0
TOTALS	12434	13837	11738	3242	4916	1772	773	53762	516	3232

Figure 5.14

Expediting Deliveries.

The function of ensuring that suppliers meet their delivery promises, commonly called "chasing", can be greatly aided by highlighting overall deliveries or by providing advance warning of pending ones.

Incorporated in the "turn-around" goods received note system, an exception report showing orders whose deliveries are late can be produced. The supplier can be contacted in such cases in order to ascertain the reason for such delays.

In the case of works orders, progress chasers can be notified so as to enable rescheduling within the plant to take place.

The sample report in Figure 5.15 illustrates. The control to be exercised may be arbitrarily decided. For example: showing items which are only one day late may yield an exceptionally large "exception" report. Thus the cut-off date may be set at any figure which is considered realistic.

In a similar manner reports can be produced detailing expected deliveries for the coming week, month, etc. From such a report orders for vital items may be expedited or reminders given prior to the actual required date.

Reconciling.

A common downfall in many inventory control systems is the discrepancy between suppliers records and that of the firm. In the case of the supplier delivering many different items, often in part fulfilment of an order, discrepancies do arise causing misunderstandings as to the availability of stock with resultant stock-outs and/or overordered positions.

By sorting the outstanding order file into supplier sequence, a letter can be generated by the computer to the supplier requesting confirmation of the outstanding position according to the firm's

OVERDUE DELIVERIES AS AT 10-06-71

PLANNER 01

ITEM #	DESCRIPTION	TYPE	SUPP# /DEPT	ORDER#	ORDER QTY	QTY O/S	DEL.DATE	PREV GRN#	DAYS LATE
1402636	LID ASSEMBLY 4PT	A	49	49631	1000	500	08-06-71	00216	2
1952671	RELAY 220V - 83819	L	H193	27316	10	10	01-06-71		9
2192321	SCREW STL BSW 5/16X1 CH	L	N031	27422	20000	20000	27-05-71		14
3284613	BODY -4PT KETTLE	F	22	22603	2000	1500	06-06-71	00344	4
5381009	CARTON- 6PT KETTLE	L	B099	27204	300	100	19-05-71	15211	22
5921000	MOTOR HOUSING CASTING	L	F327	27401	20	20	09-10-71		1
6427883	ROD BRAZING 1/4	L	D885	27321	40	40	03-10-71		7

Figure 5.15

records. The name and address of the supplier are read by the computer from the creditors file (see Appendix D).

5.6 SUMMARY OF RETRIEVALS.

The combinations and permutations of possible management and control reports are infinite, and can be designed to meet the particular firm's requirements. What has been attempted here is a presentation of the principles involved in the design of the reports, and samples of a few of them. An attempt has been made to isclated and present only the relevant information to the particular person concerned. Any computer output not read and referred to by a human being within the organisation is innocuous in its attempt to control. This is true of all information systems, as opposed to process control systems, where machines do in fact control processes. Notwithstanding the present advanced state of the art, no inventory control system can be visualised which negates the man-machine interface.

CHAPTER SIX

ASSESSMENT AND CONCLUSIONS

6.1. The Shortcomings of a Manual Inventory Control.

The problem of controlling the assemblies, components and raw materials of the manufacturing firm, has been shown to be an extremely complex one. The algorithms defined in Chapters 3, 4, and 5 offer a solution to this problem. However, the manual application of these algorithms is an unrealistic approach to the problem in the "real world" where five hundred or more product variations and tens of thousands of componements and raw materials are involved. Unscheduled changes have to be made, suppliers lead times and deliveries are statistical variables. Thus, manual solutions to the problem besides being cumbersome and clerically costly, certainly lead to substantially sub-optimal results.

It has been shown that certain groups of items require special consideration. Items are divided into "make" and "buy" categories. "Buy" items are further divided into demand and non-demand dependent categories. Manual systems must, for simplicity, have a standard set of rules applicable to each group and thus cannot deal with each item in terms of its own peculiarities.

In a manual system there is an understandable tendency to overorder. This is due to the fact that provisioning is a long and laborious process and is thus done as seldom as necessary. Updating of production programs andtheir accompanying requirement calculation is often ignored in the hope that common and standard parts will cancel one another out.

Not least of all is the fear of "stockout". An overstocked condition is difficult to detect whereas a shortage becomes apparent only too easily, usually to the discomfort of the person responsible for the control of the particular item. It is therefore understandable that the planner will avoid this condition at all costs. This situation leads to overstocking which can seriously affect the liquidity of the firm.

6.2 The Computer as a Solution.

Since the control of inventories basically involves the manipulating of data such as demand product structure and orders' data, it is logical that the most powerful of data manipulators should be applied to the problem, namely the electronic computer. The computer, with its data storage and manipulation facilities lends itself to a sophisticated solution to the problem of inventory control.

The investment in computer facilities is a large one but the economic justification can be found in lower inventory investment, fewer stockouts, less clerical error and effort, greater bulk purchasing power and lower obsolete stock levels. The reduced clerical load on production planning personnel enables greater emphasis to be placed on progress control and expediting of production. A generalised recommendation is difficult to make, however it is the writer's contention that most companies with raw material, component and work in process inventories exceeding R200,000 can economically justify installing a computer to embark on a computer-oriented inventory control system. The sizes and capabilities of computers vary tremendously but can be chosen in relation to the size of the inventories they control.

6.3 Implementation of the Computer System.

The setting up of the information files is the vital part of the implementation phase on which the sucess of application depends. Most of the required information exists in the organisation in some form or another. For example parts-lists or bills of material should be available and have only to be coded suitably. Similarly the contents of many of the fields of the inventory control file can be ascertained with a certain amount of research. Attributes of the item such as lead time, unit of measure, price etc. will certainly be kept on record by some functional department within the firm. Not all the fields of the inventory control master file need be allocated at the time of implementation. Unobtainable information may at a later stage be included.

It is difficult to estimate the period of implementation required to successfully launch a system of this nature. This depends largely on the availability of information, the accuracy of records and the manual effort applied. The implementation period may vary between three months in the case of existing computer files to eighteen months in the case of companies whose data is disorganised and unreliable. The benefits to be derived may take as long or evenlonger than the implementation period and can manifest themselves in a number of tangible ways. These benefits include lower raw material, component and work in process inventories, fewer stockouts, fewer set-ups and smaller clerical staff requirements.

It is advisable to continually track the performance and effectivity of the system in terms of its influence on the materials control aspect of the manufacturing problem.

Since the system relies on the concept of control through planning it is imperative that well constructed, realistic production programs are set-up. This implies involvement of other areas of the business such as sales, marketing and finance.

6.4 Expansion of the System.

The system essentially attempts to control the materials area of the manufacturing environment. It can, however, be readily expanded to encompass the men, machines and money areas.

The logical extension of the detailed item requirement generation is manpower and machine capacity planning, and the scheduling of these facilities for optimum throughout. Having evaluated the material, men and machine requirements to m[illegible] an objective, finance and profit planning follow.

6.5 Possible Future Developments.

The future developements of solutions to the inventory control problem are intimately connected to the development of the computer industry. With larger computers becoming cheaper and remote data processing becoming more feasible the application of computers to the control of manufacturers' inventories can be expected to increase substantially in the short term. Real time updating and reorder generation can be envisaged with extensive enquiry facilities becoming available thus eliminating the necessity for the production of long and detailed documented reports. The move away from cumbersome data collection from documents can be confidently predicted.

Mechanisation of warehouses, is an advance which can be expected to make its mark in certain industries within the next decade. In such a system the replenishment and issue from store will be controlled by a computer on whose file the coordinates of every item will be kept. Removal of items from store will update the available inventory position and trigger replenishment orders.

Ultimately and ideally all available sotck of all manufacturers and suppliers will be stored on an immense computer. By linking to this computer, any prospective purchaser may assess the availability, price procurement time of any item concerning him and register his demand for it. This highly idealised situation would undoubtably lead to an overall increase in the efficiency of manufacturers and would serve to increase the overall productivity of the nation.

The implementation of more and more sophistication systems and the extraction of maximum benefits from data processing equipment is one of the major challenges facing all those involved in improving and promoting productivity and its accompanying prosperity.

CHAPTER SEVEN

LITERATURE SURVEY.

The available literature on the subjects of computer systems and inventory control is both comprehensive and extensive. However, the literature confines itself, in the main, to the control of saleable products. Very little detailed analysis has been done on the control of the components and raw materials comprising those end-products.

Manufacturers of data processing equipment have, in recent years, responded to the needs of industry and have provided application programs for the control of their inventories. (8, 11, 12, 13, 20 and 21). These application programs tend to be extremely generalised in an attempt to make the package applicable to as large a market as possible.

The classical theories of inventory control are extensively covered in the many texts on Industrial Engineering, Production Management and Operational Research Methods. (5, 6, 7, 10, 16, 17 and 18). These theories are well known and much has been done in extending the basic theory to remove the many assumptions used to develop it.

The work done by R. G. Brown in the development of the exponential smoothing technique of forecasting, (2, 3, and 4) remains a standard in this vital area of inventory control. The application of the computer to this technique is dealt with in Reference 8, and includes a simulation program for testing the validity of the forecast.

It is the contention of the writer that the solution to the inventory problem is the use of the computer. However disciplined manual stores control and procedures are vital to any inventory system. These procedures are well defined in reference 15; and reference 22.

The effect of inventories on the macro-economy outside of the firm itself is covered in most economic texts, a good example of which is reference 19. In particular the effect of inventories on the economy of South Africa is dealt with in referance 20.

REFERENCES.

1. Inventory Management by Computer.
C.M. BOOKER.
"Stores" April, 1963. (Official Publication of the National Retail Merchant Association of America.)

2. Less Risk in Inventory Estimates.
R.G. BROWN.
Harvard Business Review - June, 1959.

3. Smoothing, Forecasting and Prediction of Discrete Time Series.
R.G. BROWN.
Prentice-Hall Inc., Englewood Cliffs, N.J.

4. Statistical Forecasting for Inventory Control.
R.G. BROWN
McGraw-Hill Book Co., New York.

5. Modern Production Management
E.S. BUFFA.
John Wiley and Sons Inc., New York, 1965.

6. Readings in Production and Operations Management.
Edited by E.S. BUFFA.
John Wiley and Sons Inc., New York, 1966.

7. Production-Inventory Systems: Planning and Control.
E.S. BUFFA.
Richard D. Irwin, Inc., Illinois, 1968.

8. Burroughs Inventory Control System.
A BURROUGHS APPLICATION PROGRAM.
Burroughs Corporation.

9. Guide to Purchasing.
Edited by: M.G. EDWARDS and M.A HAMILTON JNR.
National Association of Purchasing Management.

10. Operations and Cost.
F. HARRIS
Factory Management Series. A.W. Shaw Co., 1915.

11. Factor-Disc Bill of Material Processor.
A HONEYWELL EDP MANUFACTURING APPLICATION SUMMARY.

12. Requirements Planning System / 360 Application Description Manual.
IBM APPLICATION PROGRAM GH20-0487-2

13. System / 360 Bill of Material Processor. (360A-ME- 06X)
Version 2. Programmer's Manual.
IBM APPLICATION PROGRAM H20-0246-2.

14. The Production Information and Control System.
IBM PUBLICATION E20-0280-1. THIRD EDITION. Dec. 1969.

15. To Control Cycles, Control Inventories.
L. Mc.CRYSTAL
"Management", March 1971 - A Financial Mail Publication.

16. Production Planning and Inventory Control.
J.F. MAGEE and D.M. BOODMAN.
McGraw-Hill Book Co., New York, 1967.

17. Introduction to Operations Research.
C. WEST CHURCHMAN, R.L. ACKOFF, E.L. ARNOFF.
John Wiley and Sons Inc., New York.

18. Industrial Engineering Handbook.
H. B. MAYNARD. Editor in Chief.
Mc.Graw-Hill Book Co., Inc., 2nd Edition, 1963.

19. Economics.
PAUL SAMUELSON.
Mc.Graw-Hill Book Co., New York, 1963.

9. Guide to Purchasing.

Edited by: M.G. EDWARDS and M.A HAMILTON JHR.

National Association of Purchasing Management.

10. Operations and Cost.

F. HARRIS

Factory Management Series. A.W. Shaw Co., 1915.

11. Factor-Disc Bill of Material Processor.

A HONEYWELL EDP MANUFACTURING APPLICATION SUMMARY.

12. Requirements Planning System / 360 Application Description Manual.

IBM APPLICATION PROGRAM GH20-0487-2

13. System / 360 Bill of Material Processor. (360A-ME- 06X)

Version 2. Programmer's Manual.

IBM APPLICATION PROGRAM H20-0246-2.

14. The Production Information and Control System.

IBM PUBLICATION E20-0280-1. THIRD EDITION. Dec. 1969.

15. To Control Cycles, Control Inventories.

L. Mc.CRYSTAL

"Management", March 1971 - A Financial Mail Publication.

16. Production Planning and Inventory Control.

J.F. MAGEE and D.M. BOODMAN.

McGraw-Hill Book Co., New York, 1967.

17. Introduction to Operations Research.

C. WEST CHURCHMAN, R.L. ACKOFF, E.L. ARNOFF.

John Wiley and Sons Inc., New York.

18. Industrial Engineering Handbook.

H. B. MAYNARD. Editor in Chief.

Mc.Graw-Hill Book Co., Inc., 2nd Edition, 1963.

19. Economics.

PAUL SAMUELSON.

Mc.Graw-Hill Book Co., New York, 1963.

20. Basis 4004/26 Method and File Organisation of the Bill of Material Processing.

A SIEMENS APPLICATION PROGRAM PUBLICATION.

21. Economic Stockholding With Horest.

A SIEMENS APPLICATION PROGRAM PUBLICATION

22. Various Annual Reports of Companies Quoted on the Johannesburg Stock Exchange.

20. Basis 4004/26 Method and File Organisation of the Bill of Material Processing.

A SIEMENS APPLICATION PROGRAM PUBLICATION.

21. Economic Stockholding With Forest.

A SIEMENS APPLICATION PROGRAM PUBLICATION

22. Various Annual Reports of Companies Quoted on the Johannesburg Stock Exchange.

APPENDIX A

THE CLASSICAL INVENTORY MODEL WITH SHORTAGE COSTS

In order to obtain the optimal values of Q, the order quantity and Im, the maximum inventory level the two partial differential equations below must be solved.

$$\frac{\partial(\text{Total Costs})}{\partial Q} = 0 \quad \text{and} \quad \frac{\partial(\text{Total Costs})}{\partial Im} = 0$$

where the total inventory costs,

$$T_c = \left[C_p + C_h \frac{Im^2}{2A} + C_s \frac{(Q - Im)^2}{2A} \right] \frac{A}{Q}$$

$$= C_p\frac{A}{Q} + C_h \frac{Im^2}{2Q} + \frac{C_sQ}{2} - C_sIm + \frac{C_sIm^2}{2Q}$$

$$\frac{T_c}{Q} = -\frac{C_pA}{Q^2} - \frac{C_hIm^2}{2Q^2} + \frac{C_s}{2} - \frac{C_sIm^2}{2Q^2}$$

$$= 0$$

$$0 = C_pA + \tfrac{1}{2}C_hIm^2 - \tfrac{1}{2}C_sQ^2 + \tfrac{1}{2}C_sIm^2$$

$$Q^2 = \frac{2C_pA}{C_s} + \frac{C_hIm^2}{C_s} + Im^2 \quad \dots\dots\dots\dots\dots\dots \quad (1)$$

and $$\frac{\partial T_c}{\partial Im} = \frac{C_h}{Q}Im - C_s + \frac{C_s}{Q}Im = 0$$

$$C_hIm - C_sQ + C_sIm = 0$$

$$Im\,(C_h + C_s) = C_cQ$$

$$Im = \frac{C_s}{C_h + C_s}\,Q \quad \dots\dots\dots\dots\dots\dots \quad (2)$$

substituting (2) in (1)

$$Q^2 = \frac{2C_pA}{C_s} + \frac{C_h}{C_s}\,\frac{C_s^{\,2}}{(C_h + C_s)^2}\,Q^2 + \frac{C_s^{\,2}}{(C_h + C_s)^2}\,Q^2$$

multiplying throughout by $C_s\,(C_h + C_s)^2$

$$Q^2C_s(C_h + C_s)^2 = 2C_pA(C_h + C_s)^2 + C_hC_s^{\,2}Q^2 + C_s^{\,3}Q^2$$

$$Q^2\left[C_s(C_h + C_s)^2 - C_hC_s^{\,2} - C_s^{\,3}\right] = 2C_pA(C_h + C_s)^2$$

$$Q^2 = \frac{2C_pA\,(C_h + C_s)^2}{C_s(C_h + C_s)^2 - C_s^{\,2}(C_h + C_s)}$$

$$= \frac{2C_pA(C_h + C_s)^2}{(C_h + C_s)\left[C_s(C_h + C_s) - C_s^{\,2}\right]}$$

$$= \frac{2C_pA(C_h + C_s)}{C_s(C_h + C_s) - C_s^{\,2})}$$

$$= \frac{2C_pA(C_h + C_s)}{C_sC_h}$$

$$Q = \sqrt{\frac{2C_pA}{C_h}}\,\sqrt{\frac{C_h + C_s}{C_s}}$$

substituting for Q in equation (2)

$$Im = \frac{C_s}{C_h + C_s}\sqrt{\frac{2C_pA}{C_h}}\,\sqrt{\frac{C_h + C_s}{C_s}}$$

$$Im = \sqrt{\frac{2C_pA}{C_h}}\,\sqrt{\frac{C_s}{C_h + C_s}}$$

APPENDIX B

THE OPERATION ROUTING FILE

Although not part of the inventory control procedure itself, the routing file is a valuable extension to the system operating in the manufacturing environment.

The basic fields contained in this file are:

1. Item Number.

The item number of the factory-made component or assembly. Alternatively the address of this item on the item master file may be contained in this field.

2. Operation Number.

The number assigned to this manufacturing or assembly operation.

3. Production Centre.

The number of the centre in which this operation is performed. Alternatively this field can contain the address on the production or work centre file of the applicable centre.

4. Alternative Production Centre.

The centre in which the operation may be performed if the one specified in 3 above is fully loaded.

5. Operation Description.

A short description of the operation for example, fit, drill, ream, cut etc.

6. Tool or Die Number.

The reference to any specific tool or die required to perform the operation.

7. Set-Up Time.

The standard time, in hours, required to prepare the equipment, tools or workplace for the performance of this operation.

8. Operation Time.

The standard time to perform this operation.

9. Move Time.

The standard time to transport the item to the production centre for the next operation. In the case of the final operation the move time to the store may be included here.

10. Number of Workers - type 1.

The number of workers of labour classification 1 normally engaged in this operation. The labour classification may be in terms of "rate of pay" or "occupation type".

11. Number of Workers -type 2.

12. Number of workers - type 3.

etc.

13. Number of Operations.

The total number of operations associated with this item.

14. Contingency Factor.

The factor used to calculate the normal scrap related to this operation.

APPENDIX C

THE PRODUCTION CENTRE FILE

A production centre can be defined as a group of machines or men, usually closely situated, with a common function. In the case of fabrication or machining, machines which are basically interchangeable such as guillotines, lathes etc. may be grouped into a production centre. Assembly production centres are more commonly referred to as departments but the concept remains the same.

Each production centre is usually considered a cost centre and is controlled by a foreman, chargehand or die setter.

This file contains fields describing the contents and capacity of each production centre.

1. Production Centre Number.

The identification of the physical unit.

2. Number of Machines.

The number of machines in this centre.

3. Machine Numbers.

This may be a variable length record or may contain the address on a machine detail file of the first machine in this centre.

4. Production Centre Description.

The description of the production centre commonly used.

5. Number of Shifts.

Normally worked in this centre.

6. Hours per Shift.

The number of hours available on each machine per shift.

7. Maintenance.

The time allotted to this centre for scheduled maintenance per month.

APPENDIX D

THE SUPPLIERS FILE

For the purposes of inventory control, this file need not be extensive at all.

The following fields are useful:

1. Suppliers Code Number.

A unique number allocated to the supplier. These numbers can be allocated in alphabetic sequence making reference easy.

2. Suppliers Name.

3. Suppliers Address.

To which orders are posted.

4. Telephone Number.

To assist buying staff.

5. Terms.

Payment terms e.g. 30 days, 60 days etc.

6. Discount.

Standard settlement discount applicable to the terms above.

7. Commonly Supplied Commodities.

The item numbers of those commodities commonly supplied by the supplier.

8. Total Payments to Date.

The total payments to this supplier to date, this financial year.

9. Amount Owing.

At present to the creditor.

APPENDIX E

GLOSSARY OF TERMS

Batch Processing.

A systems approach to processing where a number of similar input items are grouped for processing during the same machine run.

Card.

A machine - processable information storage medium of special quality paper, generally $7\frac{3}{8}$ x $3\frac{1}{4}$ inches.

Card Punch.

A device to record information in cards by punching holes in the cards to represent letters, digits and special characters.

Disc Storage.

A storage device which uses magnetic recording on flat rotating discs.

File.

A collection of related records treated as a unit.

Flowchart.

A graphical representation for the definition, analysis or solution of a problem in which symbols are used to represent operations, data, flow and equipment.

Hardware.

The mechanical, magnetic, electrical and electronic devices or components of a computer.

Inquiry.

A request for information from storage.

Magnetic Tape.

A tape with a magnetic surface on which data can be stored by selective polarization of portions of the surface.

On-Line.

Pertaining to peripheral equipment or devices in direct communication with the central processing unit of the computer.

Real Time.

Pertaining to the actual time during which a physical process transpires.

Sort.

To arrange data in an ordered sequence according to specific rules.

Storage.

Pertaining to a device into which data can be entered and from which it can be retrieved at a later time.

System.

A collection of consecutive operations and procedures required to accomplish a specific objective.

Terminal.

A point in a system or communication network at which data can either be entered or leave.

Update.

To modify a master file with current information according to a specified procedure.