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M S SOUTHWORTH

AN ALTERNATIVE APPROACH TO INVENTORY CONTROL AND FORECASTING METHODS IN THE PUBLIC AND PRIVATE SECTORS

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This thesis is submitted for the degree of Doctor of Philosophy

ABSTRACT

This research was spawned by the questions and answers from the 33rd report of the committee of Public Accounts session 1983-84. The Key to the ensuing arguments about the report hinged on 3 words "Best Commercial Practice". In order to deduce a baseline the present systems of public and private concerns were investigated to find out what is actually being done. The thesis research examined what is actually happening today and in certain instances where companies have been prepared to speculate (and be open) what they believe they will be doing in the future. A review of the American and Germany Army systems has been included to ensure that the question 'best practice' could be examined between other systems having identical constraints. The research includes both new and old literature by both academics and practitioners of the science of inventory.

The hypothesis is that inventory is regarded in the singular whereas for all large concerns it should be considered in the plural, how the plural should be defined, what and how these sub inventories are and how they should be identified. The hypothesis whilst proven has the caveat that it only relates to inventories which are subject to similar structures and constraints.

The effect of implementing the hypothesis in a working environment, possible areas for future work and research, largely due to the embryonic technical breakthroughs in information technology are examined briefly. The recommendations and conclusions represent an alternative approach to inventory control and forecasting not previously covered by either theoretical or practical work.

ACKNOWLEDGEMENTS

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Finally to my wife and two sons an apology for the time not spent with them.

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GLOSSARY OF TERMS/NOTATION

ABC	Stock analysis partly based on Pareto.
Annuality	The budgeting system employed by the treasury is balanced and reallocated on an annual basis. No carry forward of unspent funds is allowed.
BASRARS	An internal MOD Study (Classified Secret).
CICP	Central Inventory Control Point.
Classification	The categorisation of inventory into sub elements for management purposes.
Close Theatre Maintenance	The generic term describing the Field Force operation.
COD	Central Ordnance Depot. A Primary Depot which fulfils a wholesale function. The depot invariably fulfils a retail function also.
Combat Supplies	Fuel, Ammunition and Food.
Depth of Stock	The stock level divided by the off take. Expressed in weeks/months or years.
DGLP(A)	Director General of Logistic Policy (Army)
DGOS	Director General Ordnance Services
DMC	Domestic Management Code. The code grouping NSNs into controllable units.
DP	Distribution Point.
DSM(A)	Director Supply Management (Army).
EMPS/EMPL	Equipment Management Policy Statement/Letter.
EOQ	Economic Order Quantity.
Fast Moving	Greater than 4 issues per year.
FQD	Forecast Quarterly Demand.
FSC	Federal Supply Classification.
FUD	Force Unit Designator.
Inventory	Stock held to support the primary function of the company. The stock itself does not generate profit.

Item Heading	Unique Part, NSN, Stock Keeping Unit.
MOD	Ministry of Defence.
Normal item	A medium-to-fast moving item with data adjusted for seasonality or growth. In most situations where consumer products, especially perishable goods, are being distributed these normal items account for between 75% and 95% of all sales.
NSN	NATO Stock Number.
Operation Overlord	The code name given to the Normandy Landings.
PAC	Public Accounts Committee.
PFS	Priority Freight System.
PRF	Provision Review Form. Computer generated document for provision analysis.
QMG	Quarter Master General.
RAOC	Royal Army Ordnance Corps.
RCT	Royal Corp of Transport.
RD	Recurring Demand.
REME	Royal Electrical Mechanical Engineers.
ROCE	Return on Capital Employed
ROL	Re-Order Level.
Secondary Depot	The status given to a distribution depot. The depot either serves a Theatre or a discrete customer. Demands are placed directly on Primary Depots.
Service Level	The level of availability that a customer can expect to receive when placing a demand.
Slow Moving	Less than 4 issues per year.
SPS	Standard Priority System.
SQD	Scaled Quarterly Demand.

Stock Out	The total exhaustion of owned, visible, stock which then necessitates procurement action.
Stock Turn	The ratio of annual sales/average stock level.
System 3	The latest redesign of the RAOC Stores System. Now redesignated 'The Stores System'.
TDC	Total Distribution Cycle as defined by the Physical Distribution Managers Handbook.
Tertiary Depot	An RAOC manned stock holding unit in direct support of a set of customers. Noramlly all stock is held on wheels.
Theatre	A geographic area treated as a block. This area many contain more than one sovereign state eg North West Europe.
U of N	Urgency of Need.
URS	Unit Repair Scale.

CHAPTER 1. INTRODUCTION

1.1. Reason for Study

The Royal Army Ordnance Corps (RAOC) is the supply corps to the British Army. The Corps was formed by the amalgamation of the Army Ordnance Department and the Army Ordnance Corps in 1918. It is responsible for all aspects of what in modern terminology is defined as the Total Distribution Cycle with the exception of the Transport element. The Transport function was separated from the Ordnance Department in 1876. The Corps as an entity should not be compared with any civilian organization. The range of products which are stored or supplied forward, range from a main battle tank, the fuel to drive it, the ammunition for its main armament down to the smallest nut or bolt used in its assembly or required to maintain it. The RAOC operates a distribution supply chain dealing in both wholesale and retail quantities to all areas within the world where British garrisons exist in Peace. At short notice in the event of war it must be capable of extending its supply chain to any area where conflict may warrant the deployment of British forces. In addition some of its commodities must be supplied to the other two services and to those governments with whom support agreements have been ratified. The customer service it strives to maintain in both peace and war can result in defeat or victory if it is not maintained at the highest required level. The cost of maintaining high service levels is a recognised fact and many profit orientated companies have by careful manipulation, at some cost to their customers, reduced their stock and and service level. This apparent good housekeeping has not gone unnoticed in government.

It has become increasingly fashionable to compare the performance of distribution systems, not only with laid down company objectives, but with the published figures of other companies or similar enterprises. These comparisons which occasionally result in strategic changes in company policy are often made without any investigation into the constraints and operational criteria between the two or more bodies being compared. The British Army supply system and to be more specific, that element operated by the Royal Army Ordnance Corps (RAOC) has recently been subject to comparison with best commercial practice.

Committee of Public Accounts 83/84.

No definition of best commercial practice appears to be available. The area of Distribution which falls totally within the control of the RAOC, subject to political and economic interference, is inventory control and forecasting methods. The research for this paper has therefore concentrated on reviewing the inventory control and forecasting methods of the RAOC and Public sector companies and best commercial practice in Private sector companies. Within the thesis, inventory will be regarded as any stock which is not held directly to generate profit but is maintained to support primary operations. It therefore follows that the total number of customers are limited and in the main have a degree of influence over what is or should be stocked. The customers will in addition have few alternative sources of supply.

1.2. Aims

The thesis examines in detail the application of inventory control and forecasting methods employed by the RAOC, other bodies and Private companies. This investigation examines the nature of the business, the policies if any that are pursued, the methodologies employed and the results achieved. Prior to comparison the thesis attempts to evaluate why such practices are employed, whether they are successful and what other options could or have been pursued. The main aim of the thesis is to examine the effect of alternative policies with regard to stock levels, customer service and economic factors. Whilst pursuing optimum inventory policies the thesis is confined to international conglomerates where the risk of stock out can and does have catastrophic effect. It does not therefore offer an optimal solution for all inventories.

1.3 Objectives

In order to achieve the aims a series of objectives were developed and redeveloped during the research. Some of the research objectives were found to stray beyond the initial aims, where these have been found to be irrelevant they have been noted but not written up. This decision was made after the number of false routes became significant from a volume of manuscript viewpoint. Their exclusion does not bias the thesis for or against the final conclusions. In the main this exclusion refers to the investigation of other companies whose activity was either too small or too discrete and specialist to warrant further investigation. Their individual inventory control and forecasting techniques are the same as one or more of the companies that have been included.

The first objective for each company or system was to examine the rationale behind the current system. Had it evolved or was it planned? Who knew about it and who managed it. Was its performance measured, how, by whom and why.

The second objective was to identify what known internal and external constraints did the system operate under. During this identification process the levels of knowledge of the inventory and its interfaces were assessed at as many managerial levels as possible.

The third objective was to define what terms of categorisation were being employed in large inventories and what these were used for. It was important that the cost of categorisation, not only financial, was evaluated. This objective was redefined to include an examination of whether constraints were peculiar to single categories or groups of categories and whether these had been or were identifiable.

The above objectives were used in the preparation and sorting of research companies in order to assess their relevance for comparative purposes. Companies were assessed for their similarity of environment, key variables and constraints.

The fourth objective was to catalogue all those methods that were available for inventory control and forecasting which had been applied to similar inventories. This research was carried out on an international basis and was not constrained.

The fifth objective was to analyse those methods used by the research companies to ascertain whether these differed from RAOC techniques and if so why.

The sixth objective was to experiment with alternative systems with a view to propounding an alternative forecasting and inventory control system. This objective was redefined when the research revealed a failing by all companies to effectively use a classification system.

The research experiments then focused on building a model which would increase the efficiency of inventory control systems.

The final objective was to test this alternative system and evaluate its efficiency in comparison with those systems currently employed.

This objective produced the data from which the recommended action and conclusions are drawn.

The aims of conducting the study are summarised as:

a. To identify whether the RAOC system is comparable with commercial companies.

b. To examine alternative Inventory Control systems propounded and used by the leading British companies with similar sized inventories.

c. To investigate the practical application of forecasting and inventory control methods within the distribution and engineering environment.

1.4. Methodology.

1.4.1. This thesis reviews the present and past systems operated by the RAOC. The RAOC in its entirety performs more than just a supply chain function, the review covers those elements of the RAOC which impinge on the RAOC inventory in order that additional constraints not readily apparent may be identified. It is not intended that all RAOC functions are discussed and in particular complete equipments such as vehicles, whilst held as stock items, will be excluded from the study. Only those items managed by forecasting formulae are included and by this limitation all Combat Supplies(1) and those complete equipments dealt with by the BASRARS(2) study are excluded. The examination whilst reviewing the structure of the organization does not attempt to offer any alternative organizational structures. It concentrates on identifying the restricting factors under which the system must operate. This investigation includes System 3,(3) the new computer software, a full description is contained in the RAOC publication System paper number 29.

1.4.2. Having identified the size, operating systems, functional activities and constraints, a literature search aimed at viewing the possible alternative methods available was carried out. This literature search was confined to clarifying the main questions raised from the identification of constraints within the present system.

Note 1. Combat Supplies are those daily needs of a soldier to fight a war. Ammunition, Food, Petroleum Oils and Lubricants.

2. BASRARS. A study dealing with war needs for complete equipments (Tanks, APCs) and Ammunition stocks. These stocks are held in addition to the normal inventory.

3. The name given to the complete computer programme which controls the RAOC inventory and forecasting.

As a literature search in its purest form no attention has been taken as to whether the authors have effectively implemented their systems. This section may therefore be regarded as what people say. The inventories that the literature search covered have not beeen limited in any way. This allows the thesis to cover options which would normally be screened out by pre-supposed limitations. The literature search has in addition examined key areas of forecasting and inventory control covered by recognised leading authors. This search highlights the major ambiguous areas within the general subject of Distribution. These ambiguities have where possible been clarified in order that there is no doubt as to the types of Inventory, Policy, constraints, forecasting and control systems which are under review. Additional subjects which broadened the research or hypothesis were examined and discussed and then either implemented or discarded. The literature covered does not relate to any particular decade but has been drawn from those publications considered relevant and still available in print.

1.4.3 Approaches were made to companies and other armies who appeared to operate similar systems to the RAOC. These companies systems were then analysed to ascertain what actual principles, objectives, policy and formulae were used or are being implemented. This section covers what people do. Having identified several major constraints further examinations of several public and private sector organizations have been carried out. These were chosen initially on their apparent similarity of role to that of the RAOC. On closer examination where it was found that they were unsuitable the research was continued up to the point where it could be proved that they could not be compared. Due to the size and complexity of the RAOC system few commercial organizations are of comparable size. Where comparison has been deemed feasible the company is compared with all or that element of the RAOC inventory which it most represents. Each organization's forecasting and control techniques has been examined.

1.4.4. The hypothesis regarding comparison, inventory control and forecasting was postulated from the research analysis carried out in both the literature study and from the participating companies. The hypothesis concentrates on whether comparisons are feasible and if they are not what alternative methods could or should be used. The hypothesis regarding inventory control is based on the classification of parts and whether the forecasting of these parts can be improved. The RAOC inventory is large and complex, the budget to support it is continually decreasing in real value. Much of the inventory is slow or non-moving. To enable the available money to be spent prudently on those items which are required for Peace and War the inventory control system must be able to differentiate between what must be bought and what is less important. This problem is not peculiar to RAOC but no efficient system is available today to enable the identification of those parts which are more important than others. The hypothetical solutions to these problems have been examined on their practicality and effect.

1.4.5 Any inventory whether it be that of the RAOC, a multinational or a small company is a vital element of the day to day survival of the enterprise. It cannot be placed in suspended animation whilst experiments are carried out nor can new ideas or formulae be run in real time with real money. As Ackoff so clearly points out 'These systems are generally difficult and frequently impossible, to manipulate and control in their natural environment for experimental purposes. Even where experimentation can be conducted and may succeed, the risk to the company is usually prohibitive'. All of the models used in the testing of the hypothesis have been based on the OR scientific approach where P = f(Ci, Uj). P = A measure of the systems overall performance and F = the relationship between a set of controlled aspects of the system (Ci) and a set of uncontrolled aspects (Uj).

In order to simulate and test the hypothesis, samples from the RAOC inventory and from the study companies were taken. The hypothesis was tested against these samples. A statistical analysis of trends in demand patterns and lead times was also carried out. The data collected was subjected to analysis with the indentifiable variables being allowed to exceed their present constraints. Known RAOC variables are covered in the functional specification for System 3.

Special emphasis was placed upon the safety stock and war maintenance reserve elements of the inventory holdings. Where possible from past data the effect of change, from peace through tension and finally war, on lead times was examined. In this context lead time was redefined to cover both manufacturer and customer lead time calculations. The research aim was to identify a simple system of classification for inventory. This classification enables the attributes of alternative forecasting principles to be assessed. Risk analysis and a review of forecasting methods forms the backbone of the research element of the paper. The main arguments are based on the concept that a spare is born, suffers a period of life and then dies. This concept is not new and it is arguable that there are more phases. Each phase of the concept were examined and variations tested. The risk of stockout under each set of conditions is quantified. This risk is further analysed and attempts have been made to define degrees of risk which could be contemplated.

Having deduced some form of classification past data from periods of peace, tension and high usage periods have had alternative systems imposed upon them. This simulation was then compared with the real data and the possible benefits identified. Life time requirement decisions for spares has also been considered at this point. Data has been drawn from normal items and those areas of high technology where the manufacturing period is short. Examples have been drawn from those equipments using micro chip technology.

Using samples of the same data collected for risk analysis and simulation the current operating procedures of those companies chosen for comparison have been substituted for the military procedures. From the results a comparison of stock held and costs incurred was carried out. Special attention has been paid to any system which increases or decreases the risk of stockouts. These comparisons on companies who have similar operational constraints to the RAOC forms the second section, that of the comparative element of the thesis. The dictates of Customer Service or individual systems forms part of the evaluation of the credibility of alternative systems. Whilst customer service for each company/organization used in the thesis is defined the base line for service will be drawn from N Maw, E Landau and M Christopher et al.

Conclusions/Recommendations. The conclusions/recommendations of the thesis will draw together the findings of the comparative elements of the thesis and identify the major areas of possible improvements. No attempt will be made to quantify the costs of implementing new systems but the expected benefits will be itemized. Areas for further study will be identified.

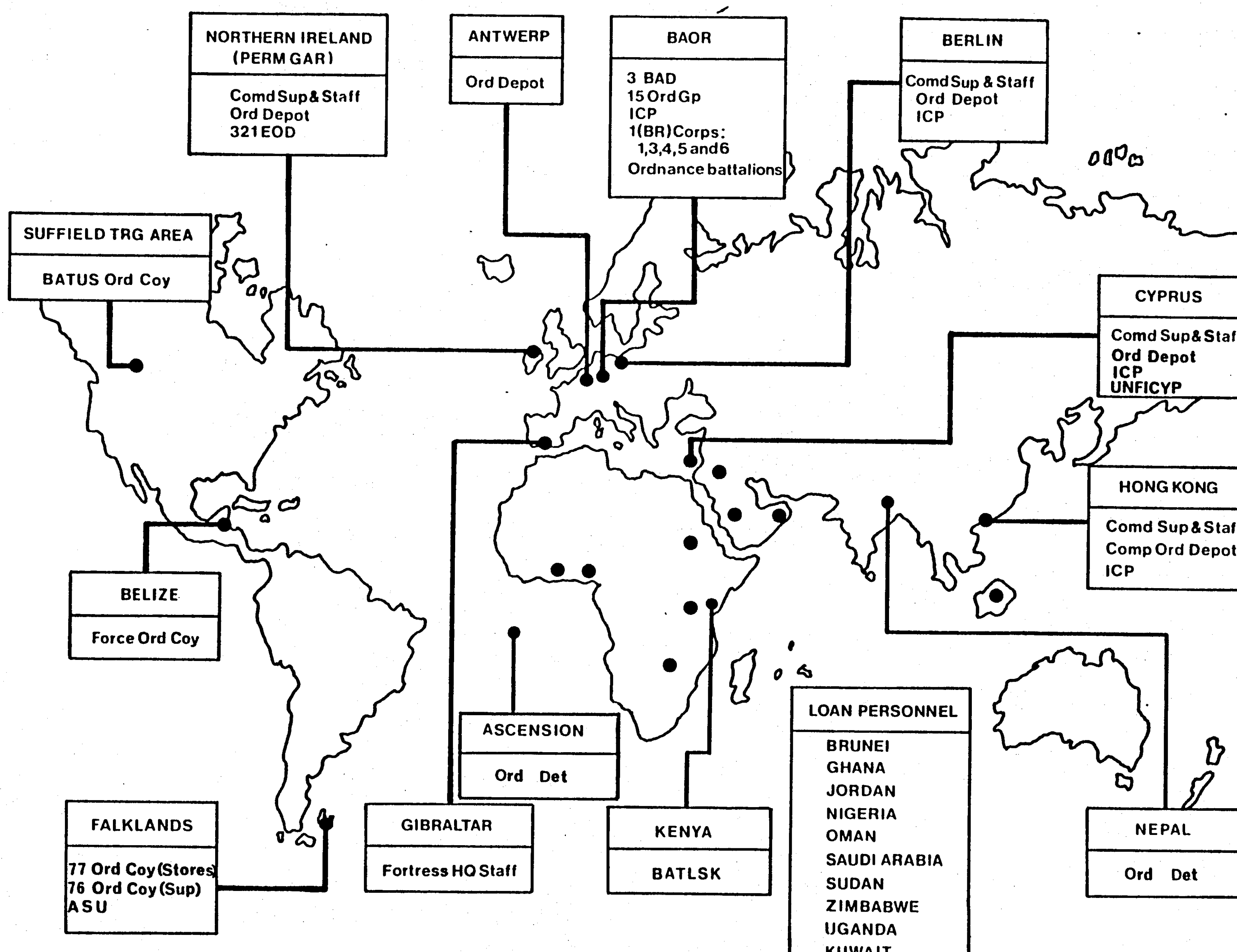
CHAPTER 2 THE RAOC SYSTEM

2.1 Introduction

The RAOC is a large multi functional organisation. The inventory and its control represent a small element of the overall objectives which the Corps must achieve. Viewed in isolation, as it sometimes is, the inventory may appear to receive less than adequate attention. It is necessary therefore to have an overview of the corporate body in which this inventory forms a part to appreciate the other elements which create a demand on finite resources.

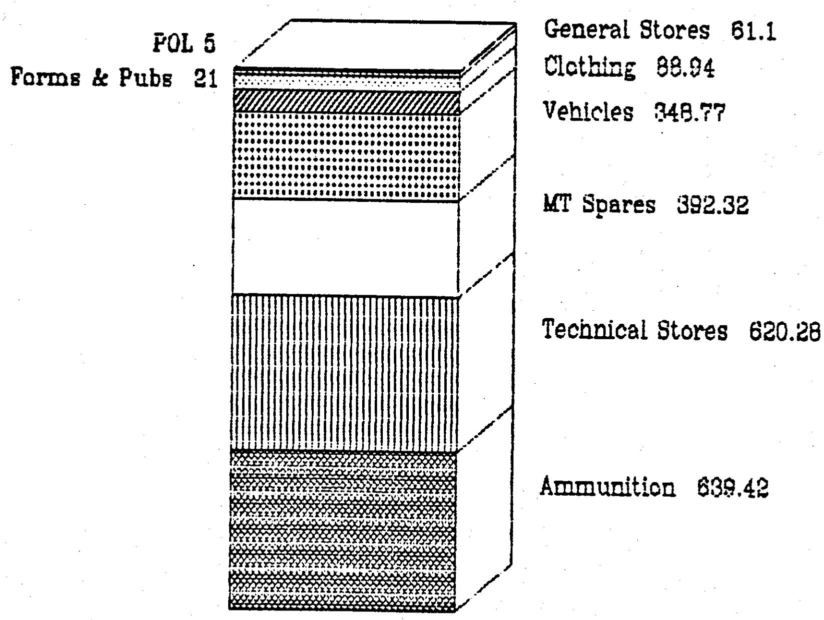
There are both uniformed and civilian manpower within the Corps and these are deployed throughout the world. The map at Figure 2-1 shows the main areas of concentration but individuals are deployed in every Western country. To fill these posts the Corps employ 1,135 officers and 6,856 soldiers who are supported by 14,343 civilians. In addition there is a Territorial Army element which in wartime would boost these numbers by an additional 95 officers and 1,733 soldiers. The total

ILLUSTRATIVE DEPLOYMENT OF RAOC OUTSIDE ENGLAND
FEB 1984



peacetime manpower required to run the Corps comes to 24,162. Comparisons are always difficult but it should be remembered that this workforce is all in Distribution related employment. With over 3 million issues per annum to its 12,000 stockholding customers (retail outlets) the workload appears large. This however represents only issues made from the stores inventory. There were 16,447 vehicles issued in 1986, 1½ million issues of forms and publications and 53,731 Tons of Ammunition. The total value of the complete inventory is in a constant state of flux but a snapshot of the UK holdings in 1987 valued the 'on the shelf' stores at £2,179 million pounds. This was broken down as shown at Figure 2-2.

Total Value of Stores UK only
Figure 2-2



Total Value £2176.83 Million

The complete inventory is not controlled by a single system nor are all items demandable. Ammunition for example is tightly controlled and customers receive an allocation for training and are reserved a given quantity for war. The war quantity is held in Theatre close to the units. The holdings are assessed from expected rates of fire based on the weapon system integration in the envisaged conflict and actual usage rates, in historical conflicts. This form of assessing stocking quantities has been applied to ammunition (including all natures of guided weapons), vehicles, fuel and food. All of these products fall outside the scope of any public or private organisation and have been excluded from the study. Forms and Publications whilst making a large proportion of issues do not operate in a normal supply and demand environment. Firstly many of the supplied items are issued against a scale and no demand is necessary. Secondly a budgetary system exists which allows short issues with no follow up back order. For these reasons this element has also been excluded. The balance of the inventory which forms the essential element of the study represents 58.9% of the UK Inventory value. To attempt an indication of the size of the problem the RAOC hold 298,300 vehicle spares to support a fleet of 101,518 multitype and purpose vehicles. General Motors carry approximately 118,000 in their inventory and UNIPART approximately 125,700.

Comparison of Vehicle Spares holdings

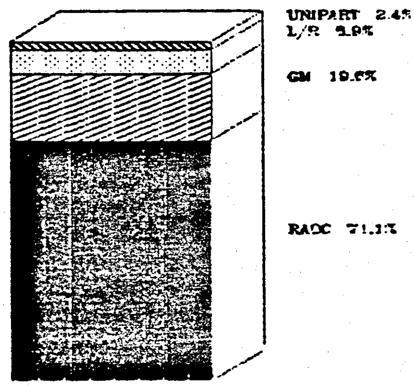


Figure 2-3

In the innovation and implementation of modern distribution concepts the RAOC have in many instances led the commercial world. Public bodies are always under scrutiny to achieve savings but these must in the main be achieved without detriment to the levels of service. Whilst public bodies are non-profit making their performance ratios must be credible. Doing more with less is best illustrated by a comparison of manpower and issue activity over the decade 1975 to 1985 and this is shown at Figure 2-4.

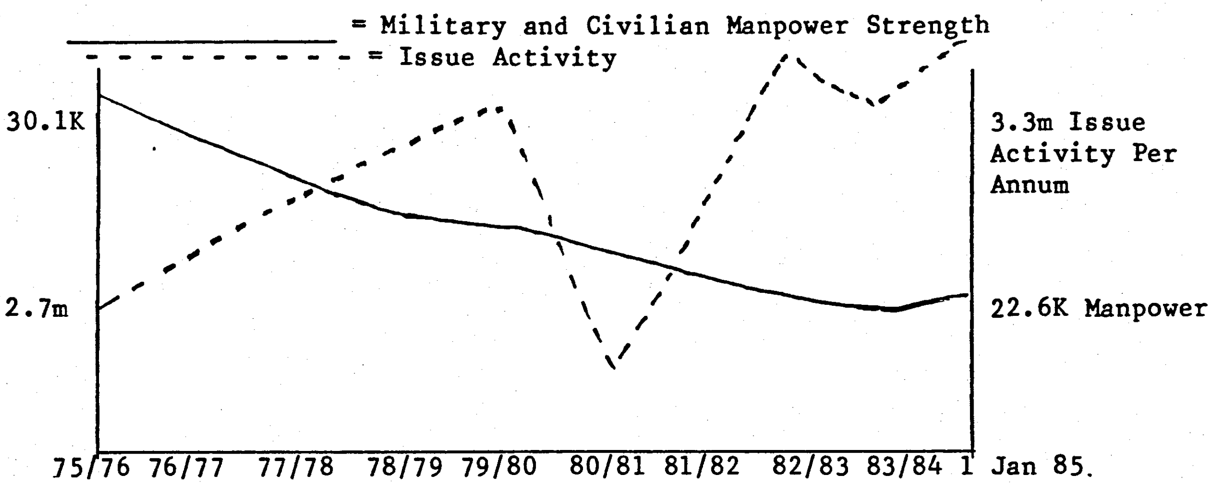


Figure 2-4

The RAOC practices in Peace for what it must do in War. The systems and manpower must be available at short notice to undergo a major transition in stock usage which it is envisaged will occur in the escalation of Tension period. Whilst it is anticipated that there will be a major surge in demand for much of our stocked items the major increase in demand will be confined to Ammunition, Fuel and Food. These items collectively known as combat supplies will form the bulk of the tonnage issued and moved in War. Spares will be provided through the static supply chain forward to the mobile supply elements which will attempt to move with the fighting formations.

2.2 Structure

The organizational structure of the Corps to allow it to function efficiently is largely dictated by the role which it must fulfil. The role of the RAOC is to supply the Army in both peace and war. Disregarding the management structure the Corps can be loosely divided by the two widely separate conditions in which it must operate. Generally the Peace element of the Corps role is fulfilled by the two large static Central Ordnance Depots at Bicester and Donnington. These two depots hold between them some 840,000 separate item headings. The depth of these holdings ranges from tens to tens of thousand individual items. The concept of maintaining large stocks of material in the United Kingdom is based partly on historical events and partly on the need for flexibility. Historically there are two major events which still influence the rationale of the system. Firstly the Dunkirk mentality stipulates that never again will so much material be committed to an overseas theatre without an adequate reserve in the home base, this policy is of course tempered by the need to have spares in strategic locations. Secondly the logistic system used during Operation Overlord in Normandy was so successful that the system has remained ever since, albeit with some improvements. The system known as Close Theatre Maintenance was based on small RAOC units following closely the fighting elements and resupplying them with fast moving stores*. After consolidation an advanced or Forward Ordnance Depot would then be set up to supply a far wider range of fast moving stores and hold a reserve for the smaller units. Items of supply which were not classed as either fast moving or essential would be supplied by the home base from Base (now Central) Ordnance Depots. These large Ordnance depots would in addition hold reserves of all items held forward in order that the loss of forward stores holdings would not have catastrophic effects. This system which has been modified and updated, mainly through the advances of communication and transport technology, is known as the stockage support system. An overview of the current deployment is at Figure 2.5

*Fast moving stores - Those stores considered essential to maintain the efficiency of the fighting formations.

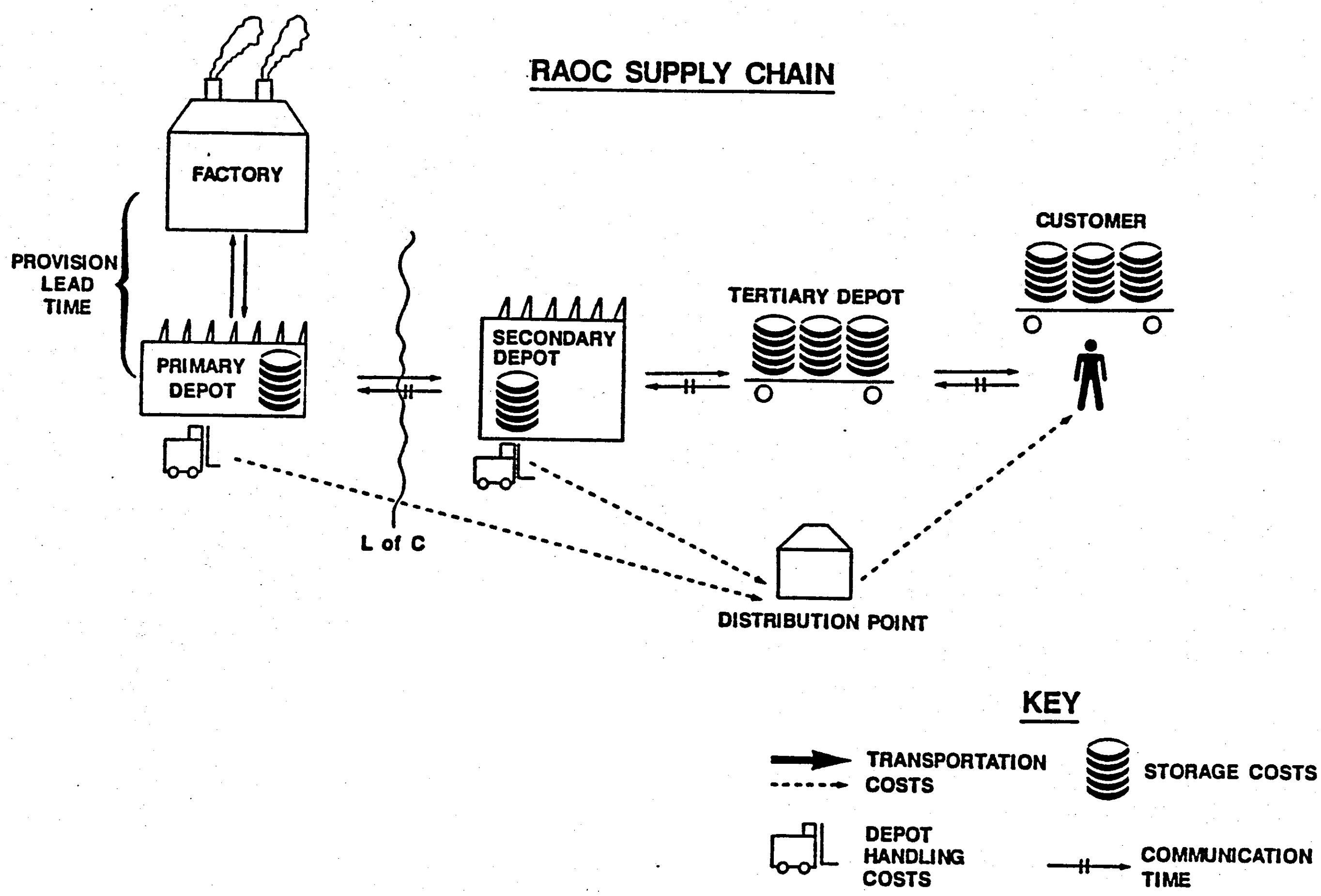


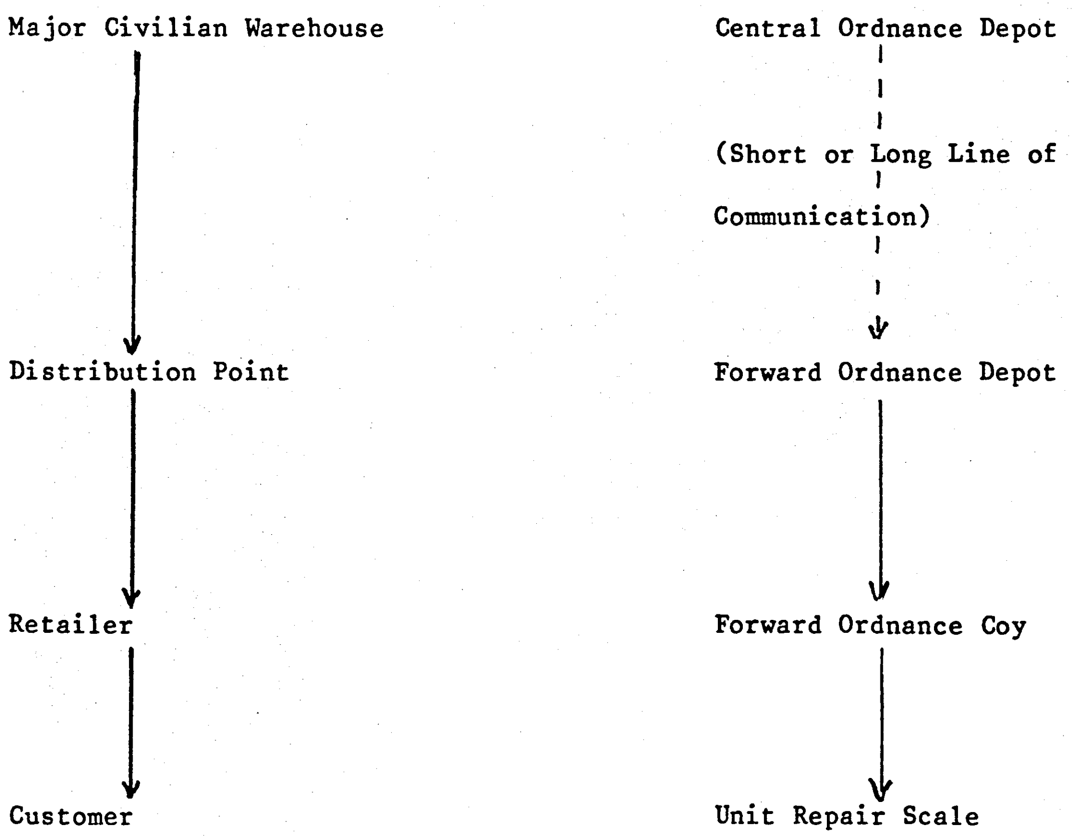
Figure 2-5

The need for flexibility by the RAOC supply system is dictated by government policy and world crisis. The supply system must react to the needs of the army and these needs are mainly dictated by the Defence white papers and Foreign Office policy. The British army has fought since the last war in almost every type of climate from the scorching sun of Aden, the jungles of Malaya, to the freezing wastes of the Falklands. This drift in the Theatre of operations makes it imperative that large stocks of equipment for many types of conflict in varying Theatres are available at short notice to be moved to any point where they are required. Whilst an Empire existed it was more expedient to disperse the stores nearer to those areas most at risk. The vast losses of stores after Suez and Aden concentrated the planners' minds to the view that the only secure way of maintaining flexibility and ensuring availability was to hold large stocks in the home base. This policy automatically requires large stocks of spares which receive little or no demand in peace but large demands in specific scenarios. It is often these stocks which are chosen as examples for 'overstocking' allegations by Public Accounts bodies.

The peace time supply is concentrated on the receipt and issue of all items through the Central Depots. These depots have little if any role to play in the conceptual war which, in North West Europe, the strategists believe will be of short duration, high intensity and involve heavy losses. The scenario envisages a period of tension during which all war reserves will be out-loaded from the Central Depots and moved to the theatre of operations. Once this is completed the depots may be required to make further issues but this will be dependent on their surviving hostile action by conventional, chemical or nuclear strike or by guerilla type activity.

The brunt of supply during war will be borne by the Forward Ordnance Companies and the Forward Ordnance Depot. The forward ordnance company is a small mobile unit which has an inventory of approximately

13,000 item headings of fast moving essential spares which are stored on vehicles. Its role is to follow as closely as possible the fighting formations which form its dependency. In addition to these Companies each fighting unit carries a limited scaling of between 2-5,000 item headings. These stocks, known as Unit Repair Scales (URS), are supplied, replenished but not controlled by the RAOC. The Forward Ordnance Depot in the theatre of operations is expected to continue issues until hostilities prevent them, but in addition, to simultaneously outload into the field sufficient stocks to enable replenishment to continue. All of these units exist in peacetime and therefore the Stockage Support System is practiced in peace in order to improve the probability of its efficiency in war. The system is not dissimilar to the normal civilian distribution flow.



<u>Supply Chain Flow</u>

Figure 2-6

The senior management of the Corps is organized on similar lines to a civilian company. The Corps may be regarded as the distribution element of a much larger Corporation. The director who is responsible for the smooth running and effectiveness of this operation is the Director General Ordnance Services (Major General rank). Whilst responsible for the implementation of most policy and operational decisions he is responsible to the Quartermaster General who co-ordinates all logistic and support operations for the Army. The QMG's department is responsible for the:

a. Formulation of logistic policy for the Army.

b. Logistic aspects of plans, operations, logistic organisation and logistic development.

c. In service management of weapons, ammunition and equipment.

In order that these responsibilities are effectively implemented the following directive is placed on the Director General of Logistic Policy (Army) (DGLP(A)). The elements of the directive that appertain to this thesis are:

DGLP(A) is responsible for:

a. The planning and execution of all Q aspects of operations.

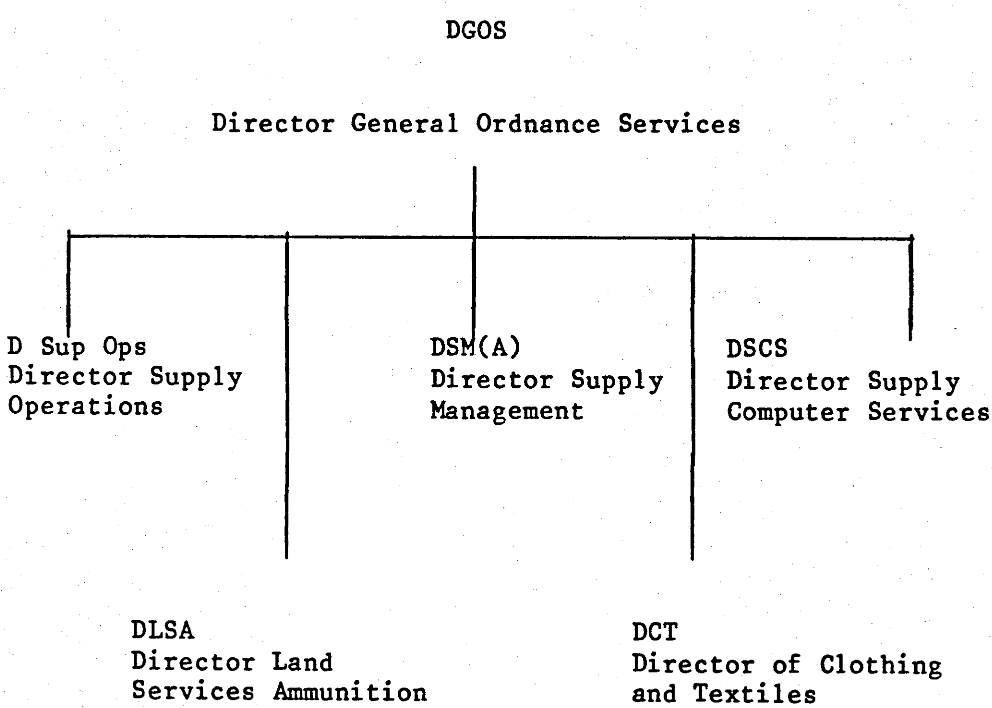
b. The policy for stocks and resources within levels laid down by the General Staff.

c. Logistic Policy, doctrine, development and studies.

d. Q aspects of combat development and logistic support planning for new equipment.

e. Co-ordination of in-service equipment management.

It should be clear therefore that whilst the Corps is a separate entity it is not autonomous. The major functions within the Corps are sub-divided into 5 areas, each having its own Director (Brigadier rank). These are shown below.



RAOC Organisational Chart

Figure 2-7

It is important that the actual responsibility of each of these directors is made clear.

The Director Supply Operations is the DGOS's staff officer for management services, storage and related matters. He exercises functional control and co-ordination over the Central Depots.

The Director Land Services Ammunition is the equipment manager for all land service ammunition. His responsibilities include development, inspection, training and explosive ordnance disposal.

The Director Supply Management is responsible for supply management policy throughout the Army. He is also the individual manager for those equipments for which the DGOS is the nominated equipment manager.

The Director of Clothing and Textiles is responsible for the design, trials and introduction of all items of clothing and textile equipment.

The Director Supply Computer Services is responsible to the DGOS for the design, implementation and management of supply computer services world wide.

The responsibilities of both DLSA and DCT have been deliberately included even though their areas of interest fall outside the scope of this paper. Their demands upon both DSM(A) and DSCS for both manpower and computer programming time need to be mentioned at this stage and will be reflected later in the paper.

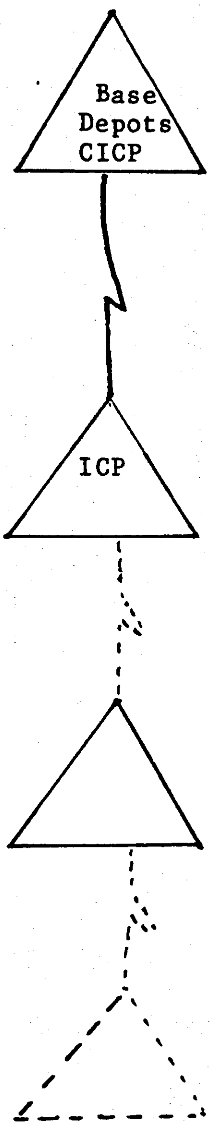
2.3. Evolution of Automatic Data Processing (ADP)

The Corps were not tardy in seeing the exciting new challenges and opportunities presented by computers and ADP methods. The first computer systems were installed in Chilwell and Donnington in 1963 and 1964 respectively. As with all companies experimenting with new technology, mistakes, whether from overcaution, underestimation of capability or inefficiency, were made. Implementation was however a major step forward. The lessons learnt from this early start were that there was a serious loss of potential if only existing manual systems data is transferred to computers. The opportunity to either increase the data base, build in flexibility or allow greater automation was lost. It is easy to look back and pick faults. At the time in question any person capable of understanding a computer never mind being able to program one could earn far more out of the Corps than in it. The loss of manpower from the armed forces and the civil service restricted the options available. Disregarding Maslov's hierarchy of needs, for specialists when they are in demand, has always created problems for public bodies. The inability to promote early or increase incentives has resulted in a constant drain on DSCS manpower which is still occurring. During the early use of computers the effects were at times disastrous. There is an oft quoted example where an automated Provision Review Form generated a buy for a million gallons of battleship matt grey paint. The demand causing the buy was for 5 gallons. This early distrust was not replaced with confidence and even today total acceptance of ADP has not been achieved. This failure to find acceptance is based partly on the fact that many of those non-specialist workers who have lived through the evolution are still working in the same depot 10 and sometimes 20 years on.

The initial mistake of transferring a manual system to a computerised system has to some extent been remedied. The programs have however erred on the side of pure data processing as opposed to manipulative interactive systems. In 1970 the Corps centralized its computer operations on CICP Bicester from where the total inventory is controlled. The Central Inventory Control Point system is justifiable because central provision, procurement, accounting and control could be exercised over the greater part of the range of material of RAOC supply. This centralization was however judged feasible only if all natures of stores were treated by the same programs and stock requirements calculated using the same formulae.

The RAOC computer systems operating within the RAOC Stores Supply Chain in 1988 are as follows:

Chilwell
1 x ICL 2903 | 1 x ICL 2966/39 | Donnington



Base Depots CICP	1 x ICL 2966 Dual 1 x ICL 2996/39 2 x ICL 2960/10 1 x ICL ME 29/37	Primary Depots includes CICP. Total Holdings 840,000 item headings
ICP	1 x ICL ME 29/45 Direct Link to CICP	Secondary Depot BAOR ICP BAOR Holding 80,000 item headings
	COFFER stand alone Micro Upgrade due in 1992 possible increase to on line facility.	All major Tertiary Depots (including Armoured Divisions Companies and some Stores Platoons/ Sections) Holding 10 - 16,000 item headings
	UNICOM Stand alone micro.	688 Major Customers Implementation expected in 1992. Min requirement is Modem Max is on Line

<u>ADP Deployment</u>

Figure 2-8

2.4. Current Methods

The present system is being phased out and a new process, designated System 3, has been introduced. This section is based on the Army CICP System 3 papers. Once again the calculations and control procedures are designed to cover the complete inventory but manipulation of individual spares forecasting and control is technically possible. The process of management by exception is intended to reduce managerial attention only to those items that are causing supply problems. The greatest attention is focussed on those items experiencing shortages whilst those in equilibrium or in excess are largely ignored. The basic tenet of the system is the assumption that future customer demand is known and unchanging. The reason for this assumption is that the systems main aim is to allow forecasting to be carried out routinely. The only area in which this aim does not apply is new to service items.

The system is satisfactory when the finances allocated to it are sufficient to buy what the provision calculation recommends. When money is cut or reduced there is no method to decide or define what is important or what is not important.

System 1 was the title given to the first computer operated stock control system introduced by the RAOC. Under this system the previously manually operated system was transferred almost intact onto large computers installed in the two major COD's. (Donnington and

Chilwell). The manually calculated system had utilised EOQ and ROL calculations and these were transferred onto the computers. In 1970 with the installation of a more modern computer system at Bicester the two ageing computer installations were demoted to satellite status. In 1972 the management of the total stores ranges was vested in the Central Inventory Control Point (CICP) at Bicester and this element became part of DSM(A). The category 1 inventories of Ammunition and Equipments (VESPER) have been introduced as separate systems on the Bicester installation. All three commodity systems were collectively known as system 2 and interacted with RAOC computers in BAOR, Berlin and Hong Kong as well as with other defence computer installations. In late 1986 a new computer installation with updated software was installed at COD Bicester. Two 2960/10 machines are in use to handle the vast majority of the installations produced workload providing some 7,200 megabytes of data. The main RAOC Secondary Depots are on line to CICP and operate with ICL ME 29/45 hardware. First generation computers are operated by major tertiary units who now down load daily in BAOR to secondary depots. Eventual expansion of the system with the introduction of AQUUS/UNICOM may give total visibility of stock to customer level. This project is still some years away from implementation and is dependent on funding.

As has already been stated the RAOC inventory is driven by the standard EOQ formulae. The presentation of the formulae is represented as:

$$EOQ = \sqrt{\frac{2\ CO \times 4 \times FQD}{Ch \times P}}$$

Where:

CO = Cost to Order.

CH = Cost to Hold.

4 x FQD = Forecast Quarterly Demand x 4 = Annual forecast Demand

P = Computer held price.

Within System 3 $\frac{(CO)}{(Ch)}$ has traditionally been represented by a K factor which could be set for MT, Clothing, Tech and General stores. In practice K has not been altered or amended. (One recorded change 80-87). P has normally been taken as the latest quoted price but the interface between provision and procurement has not been sufficient to allow trade off modelling. The ADP system does not have a modelling facility but recalculation can be achieved by re-inputting the Provision Review Form with amended EOQ variables. This, at present, however effectively increases the Lead Time and thereby the quantity of unnecessary stock held.

The technique used for forecasting usage is still reliant on exponential smoothing. The forecast is made for one time period ahead (period dependent on procurement policy) and is the weighted average of the quantity demanded over past time periods such that the:

$$\text{Forecast Demand Quantity} = \alpha \times \text{Quantity Demanded in Latest Period} + (1-\alpha)\ \text{Previous Forecast}$$

The α constant is related to the quarterly rate of movement. Slow movers are regarded as those items for which only one recurring or no demands have been registered in the last four quarters, Total Demand=1 and for these the α constant is 0.1. Should an item classed as a slow mover receive one demand in at least 4 successive quarters then the constant will be raised to 0.2. All other items will receive an α constant of 0.2. A breakdown of the annual throughput per item is shown in Fig 2.10. It should be noted that 78% of the total inventory falls into the category of slow movers whilst a further 13% can be classed as relatively slow movers. The actual working inventory or live items are in fact less than 9% of the total.

The inventory is subdivided into four groups for management purposes. These groups are:

1. Technical stores.
2. Clothing.
3. MT Stores
4. General stores.

The average demand patterns are shown in figures 2.10a, b, c, d.

This demand frequency whilst appearing erratic is symptomatic of the support policy. All equipments are supported but for those regarded as warlike stores the scaling (based on the number of essential parts required per 100 vehicles) is set at a level allowing total availability in line with the MOD Equipment Management Policy Statement. This is normally set at about 97% availability permanently with an increase to 100% after a short duration (normally 48 hrs). Those spares with a low Mean Time between failure and regular wear out constitute the bulk of the annual turnover and spend. The RAOC annual spend from the 2K1 vote heading for 1987 was:

Vote 2K1 Spend

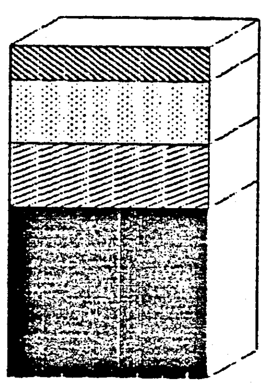


Figure 2-8

The current (1988) Annual stock turn is in the region of once every 2 to 2.5 years (commercial calculation is ½ to 7/16)
which is in line with the EOQ(C) which has an upper setting of 3 years.

BREAKDOWN OF STOCK BY ALLOCATION

Earmarks. Stock committed to a customer or project but not yet issued.

War Reserve. Overall representative percentage less than 1.8%. However Gen Stores is approx 10% of total holding whereas MT represents .24% of total holdings.

Safety Stock. A buffer stock the area first put under review in most coy's when economies required represent only 3.35% of total inventory cost. This is probably justified in that safety stock is only really carried on those items being used or expected to be used.

Free Stock. 77.4% of total Inventory Cost is tied up in inventory holdings this represents some £895,273,040. Estimated annual turnover = 404,750,034. Theoretical stockturn once in every 2 years. ie Stockturn = ½.

Breakdown. The breakdown of the inventory value by the four RAOC groupings is shown at figure 2-11.
The total stock of an item is made of Free Stock, Safety Stock, War Reserve and Earmark Stock.

Figure 2-10

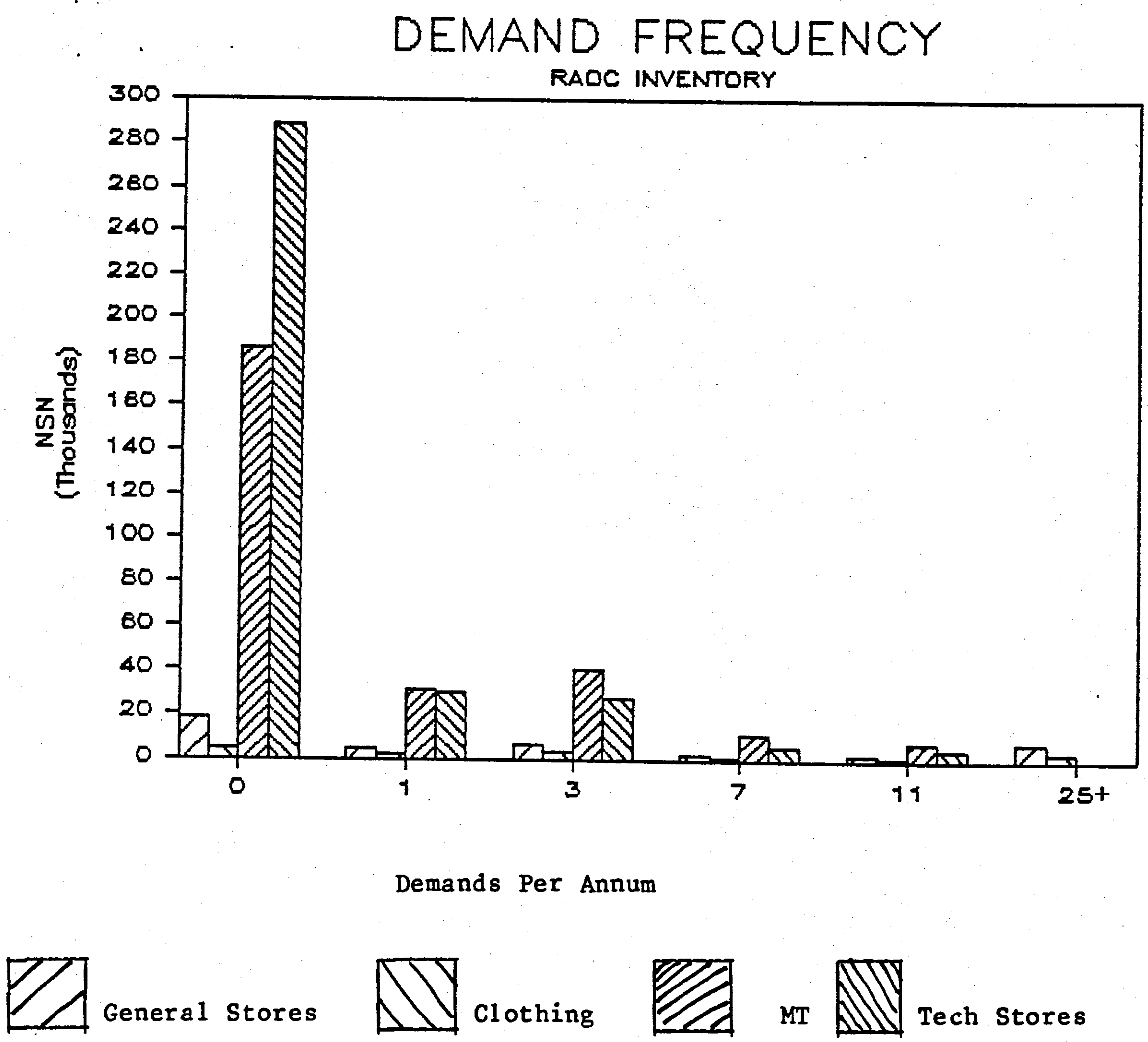
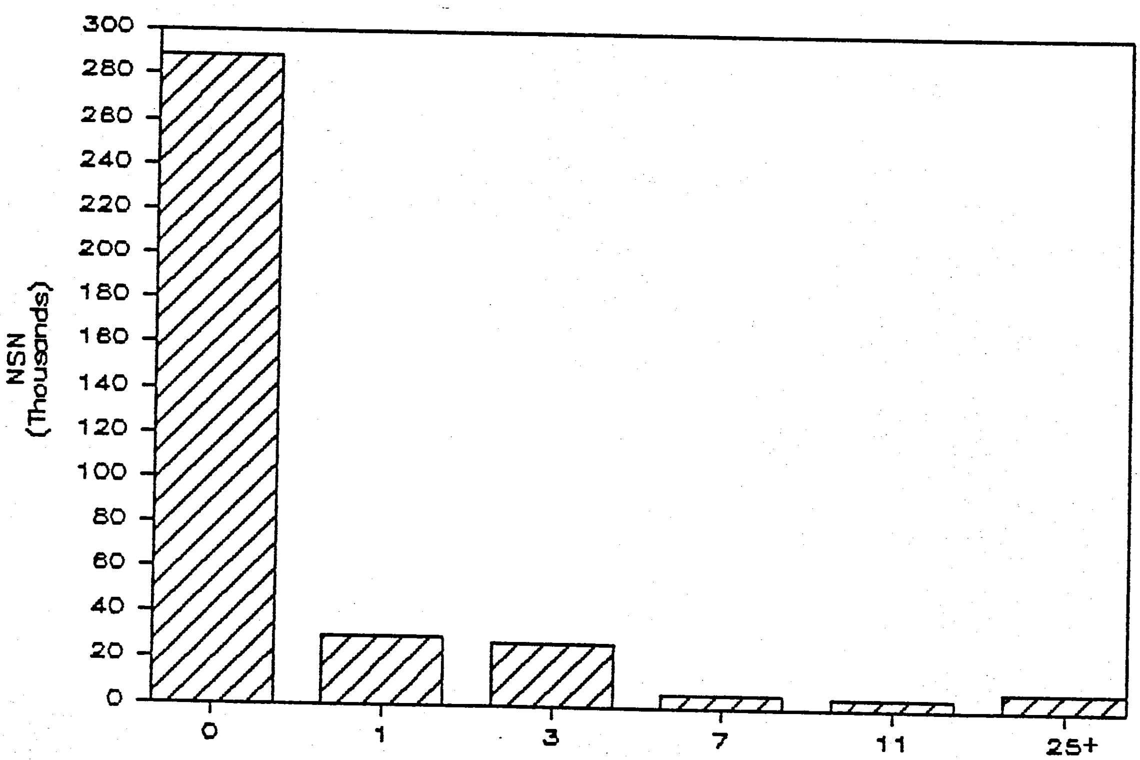

DEMAND FREQUENCY
RADC INVENTORY
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
NSN (Thousands)
0
1
3
7
11
25+
Demands Per Annum
General Stores
Clothing
MT
Tech Stores

Figure 2-10-a

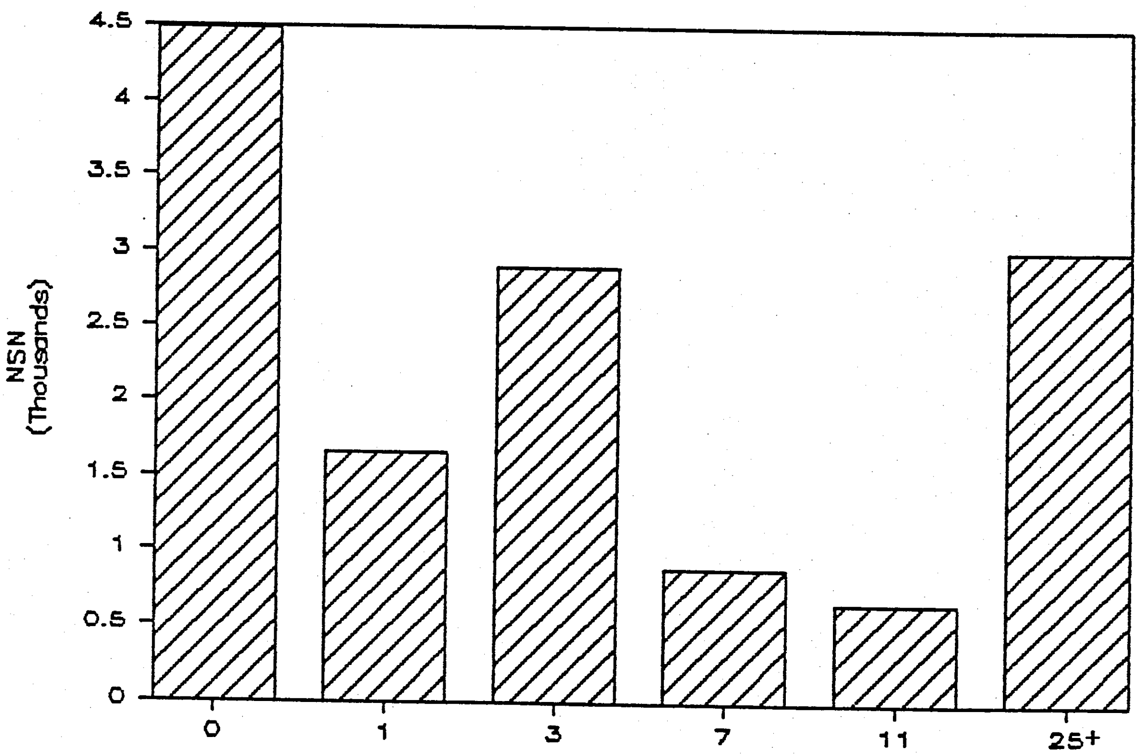
TECH STORES



DEMANDS PER ANNUM

Figure 2-10-b

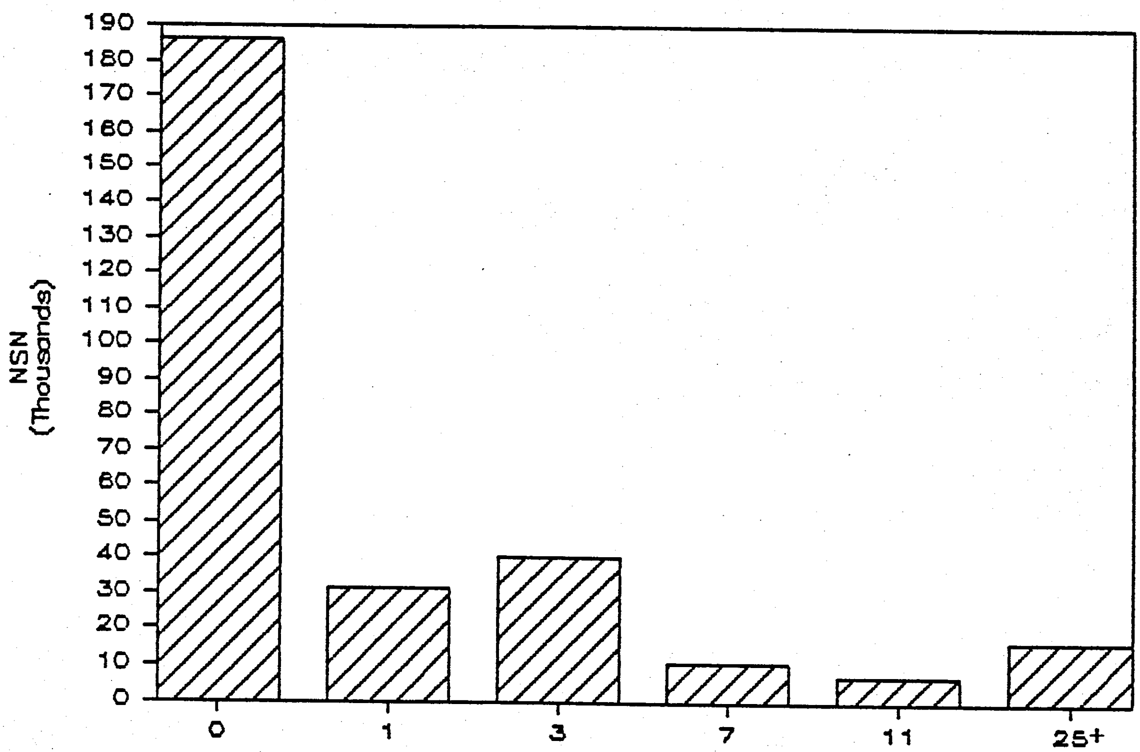
CLOTHING



DEMANDS PER ANNUM

Figure 2-10-c

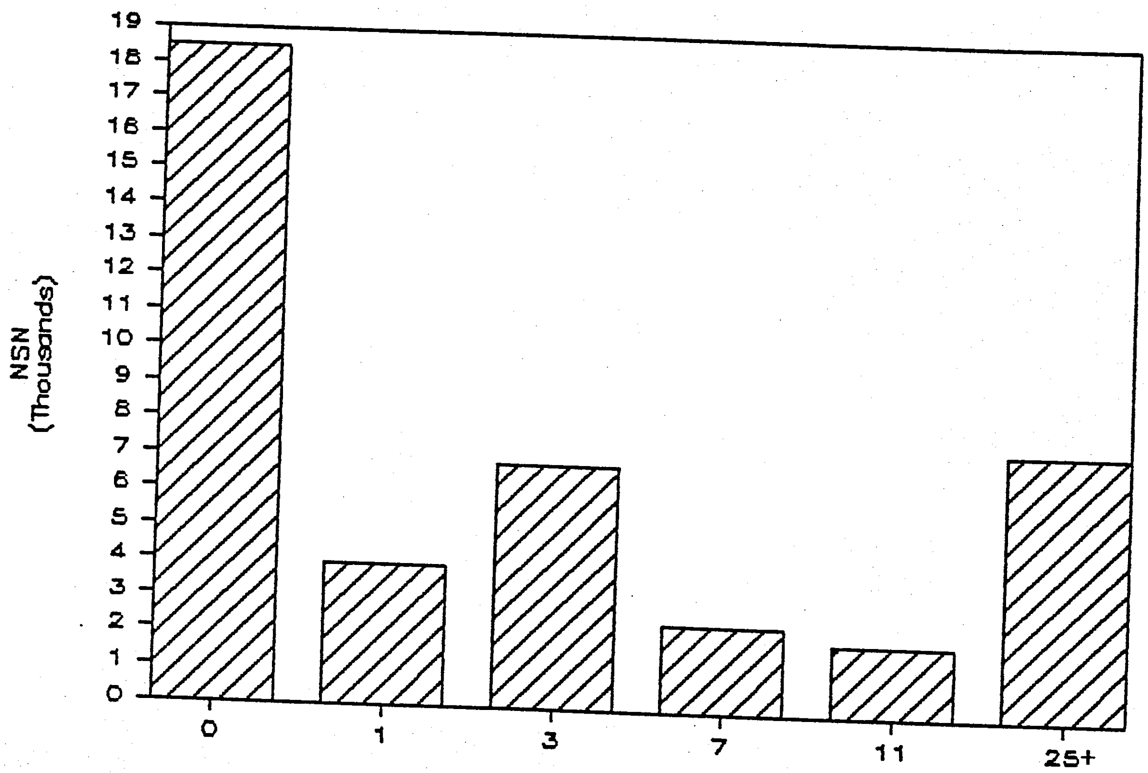
MT



DEMANDS PER ANNUM

Figure 2-10-d

GENERAL STORES



ISSUES PER ANNUM

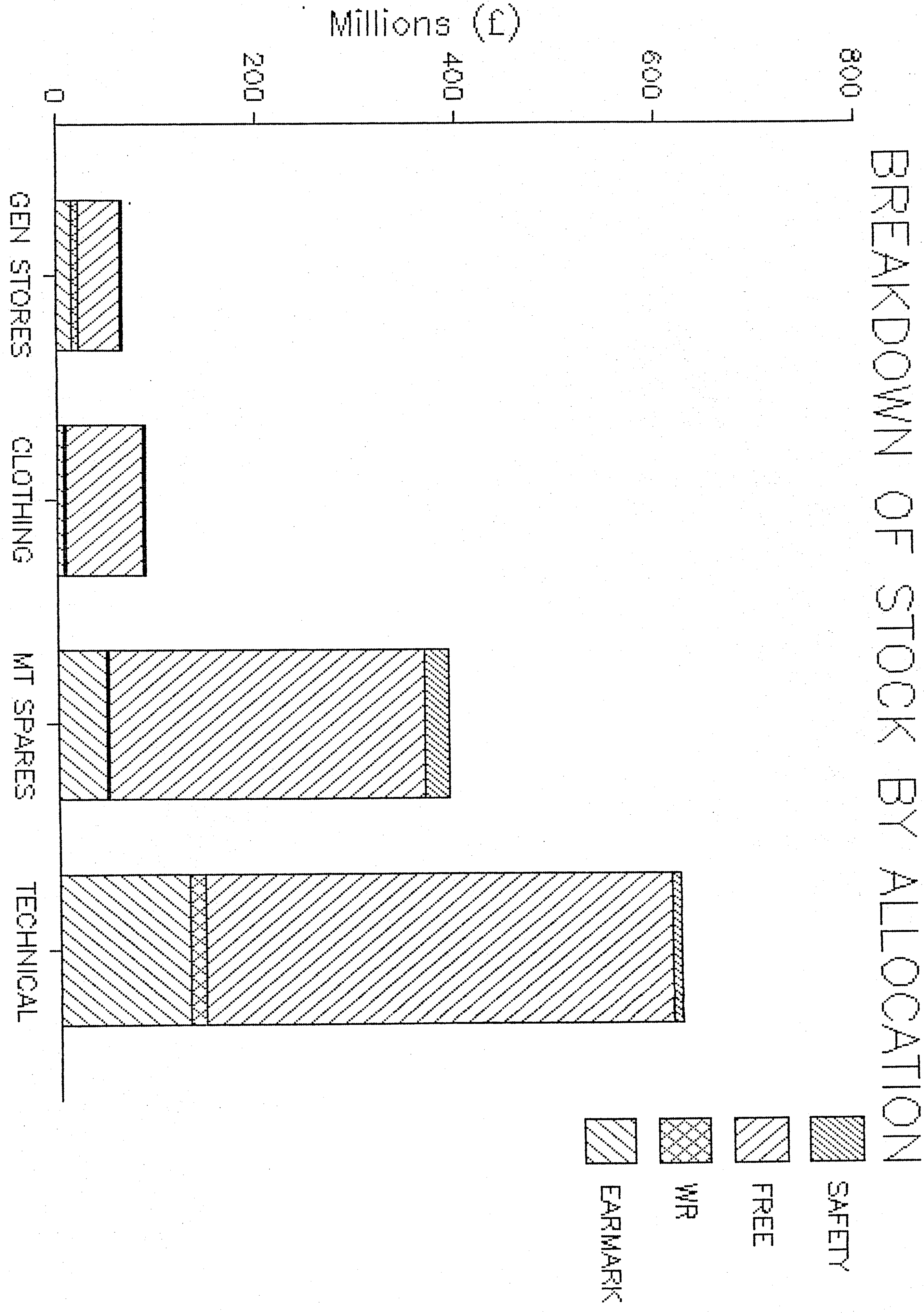

BREAKDOWN OF STOCK BY ALLOCATION
Millions (£)
0
200
400
600
800
GEN STORES
CLOTHING
MT SPARES
TECHNICAL
SAFETY
FREE
WR
EARMARK

Figure 2-11

STOCKING SECONDARY AND TERTIARY DEPOTS

2.5 The concept of secondary and tertiary depots was outlined in paragraph 2.2. The stocking of these depots is initially based on the number of equipments deployed to the theatre in which they are geographically located. Once demand experience is being generated the system is driven by what is referred to as the Stockage Support System. The controlling depot which feeds spares forwards is responsible for maintaining the historical records on usage for its associated depots. The secondary depots are therefore responsible for maintaining the historical data for all tertiary depots in their theatre. Primary depots will hold the data relevant to the historical demand pattern for secondary depots. The physical stock holding at each level forward from primary relates to the laid down policy on the depth of holding of stocks plus the safety factor element to cover the expected lead time of the movement of stock from each depot forwards to its dependency. A movement of stock forward for replenishment is driven by the well tried and tested reorder level process. Tertiary depots are severely constrained on what they can hold because they must retain the ability to remain mobile. Part numbers which exhibit no movement over a fixed period of time are recommended for outscaling whilst those that have registered a laid down number of requests are recommended for inscaling to the tertiary depot. This process, while it appears relatively simple does not take account of the different expected levels of consumption which would be experienced once the change from peace to war has taken place. Tertiary depots therefore have the facility to disregard outscaling recommendations where they believe those parts will be required during war even though they exhibit no movement during peace. This is also true for inscaling suggestions where the Officer Commanding believes that the requirement is purely a peacetime requirement and does not reflect a realistic usage in a war environment. An example of the predicament is the usage of wing mirrors for vehicles, their requirement in peace is to ensure that units may train for war without infringing peacetime civilian regulations, during war there will be no requirement for wing mirrors. The dilemma which faces most tertiary depots is that the efficiency of the unit is rated against its ability to supply spare parts in a peacetime environment whilst the policy for its existence states that it is there to supply the dependency in peace and war. An ABC analysis of the inventory held in a tertiary depot would not reflect a true picture of the effectiveness of a fighting unit to perform its laid down role. Many of the spares used in peacetime have no use in war. Decisions regarding the criticality or essentially of spares within the tertiary depot inventory are made at present on calculated judgement or gut feeling. No formal system currently exists which will allow a Tertiary Depot Commander to work out using any form of logical sequence whether or not he should hold a particular spare. The dilemma is further exacerbated by the requirement to achieve flexibility within Divisions. The units or customers which the Tertiary Depot is asked to support may due to circumstances apparent to the Commander of the total force be changed at a moment's notice. In addition the units supported during peace are not the same as in war because of the post World War II historical and geographical availability of barracks. The holdings which he has would have been based on a fixed number of units whereas once war starts the chances of the Battle Group or Battle Groups whom he supports remaining as part of his formation are in doubt.

THE STANDARD PRIORITY SYSTEM (SPS)

2.6 The RAOC system aims to provide a fixed quality of customer service at the minimum possible cost. The current service level aims at meeting 95% of all demands placed for the complete inventory. Any attempt to increase the service level beyond 95% will automatically be accompanied by a disproportionate increase in the cost incurred within the inventory. This increase in cost makes it fairly clear that there will be a constant battle between what the Corps would like or are able to achieve, the Army can afford to buy, and what the customer requires. This trade off between the inventory held and the customers needs means that there is a requirement for some form of rationing. This rationing applies not only to our physical resources of spares but also to the movement of these spares and the management required to provide the best service possible. The SPS exists to provide a means of ensuring that the units with the highest operational status receive stocks first. The effectiveness of the Standard Priority System (SPS) and therefore its value to the units depend on how those units choose to operate the system. It is a matter of choice because whilst there are checks in the system to identify misuse or abuse the sheer volume of demands being processed makes these checks relatively ineffective. The Central Ordnance Depots are making nearly 3 million issues a year, roughly 60,000 each week. The RAOC can only operate the system, the units who are the customers can decide the degree to which the system will be effective.

The SPS is based on 2 major factors. The first is the Force Unit Designator known as the FUD. The second is the urgency of the requirement known as the U of N (Urgency of Need). When the 2 are matched in the SPS matrix they form the priority code at which a unit should demand spares. The matrix is shown at Figure 2.12%.

The FUD is calculated by the Ministry of Defence and relates to the importance in the order of battle of each individual unit within the British Army. Units are assessed as to their contribution to the war winning element of their role in war. Only the Ministry of Defence can change a unit to FUD 1. FUD 2 to FUD 4 are allocated by HQ UKLF and HQ of Commands. FUDs are not open to discussion. The majority of units will become FUD 1 units once hostilities commence.

The ability of units to manipulate the system to get what they want or need, when they want it, is decided by the urgency of the requirement. U of Ns are letter coded A to E and relate to a time scale in which

HE STANDARD PRIORITY SYSTEM

A GUIDE TO THE SELECTION OF PRIORITY CODES IN THE PREPARATION OF DEMANDS
(JSP 336 Pamphlet No.3)

MOD FORM 345 C REVISED 1982

1 SELECT THE URGENCY OF NEED (U of N) CRITERIA MATCHING YOUR REQUIREMENTS

A	B	C	D	E

2

D ACROSS M THE OF YOUR T TO YOUR ECTED F N UMN TO IVE AT PRIORITY E TO BE D

FUD	PRIORITY CODES				
I	01	02	05	09	13
II		03	06	10	14
III		04	07	11	15
IV			08	12	16
NK OF AUTHORISING OFFICER					

				WORKING DAYS	WORKING DAYS	WORKING DAYS
PELINE MES FOR CAL ANNING aragraphs & 29 of P 336 mphlet 3)	STANDARD TIME	FASTEST POSSIBLE MEANS				
	LOCAL TIME FROM THEATRE TERMINAL	FASTEST POSSIBLE MEANS				
	TOTAL PIPELINE TIME	FASTEST POSSIBLE MEANS				

TES

e paragraph 16 of JSP 336 pamphlet No.3 for full details of URGENCIES OF NEED criteria the RAOC in conjunction with the RCT will deliver spares. A B and C U of Ns relate to operational vehicles and equipments only. This point is often overlooked by units and a definition of operational vehicles tends to be dictated by the wishes of the Commanding Officers. The Commanding Officers wishes often override the stated policy on operational levels laid down in EMPS/EMPL directives. A recent 01 priority demand, normally only used in war, for an ash tray for a staff car highlights the abuses placed on the system. The pipeline times which are laid down to various theatres indicate to the customer the exact time that he will have to wait for his spares to arrive in his location. These pipeline times are made up of the communication time, the depot processing time and the delivery time. The movement of spares from both primary and secondary depots is the responsibility of the RCT. Dedicated vehicles running on fixed routes to laid down schedules cater for the vast majority of spares demanded on the RAOC system. The Standard Priority Systems smooth operation is dependent upon the communication time and the depot processing time for each priority not being exceeded. Each Priority Freight Service route terminates at centrally located distribution points (DP) around which are grouped military units demanding on the system. The DP has the responsibility for sorting these spares and issuing them to units. The major anomaly within this system is that tertiary depots must also participate. Tertiary depots demanding spares to restock their shelves may normally only be allowed to demand at a priority 15.

Customers requiring their spares at a far greater speed when URS stockout situations occur can "outbid" the tertiary depots and demand through the tertiary depot directly on to the secondary depot at a far higher priority.

Spares Availability. Whilst the SPS is monitored to evaluate the ability of the logistic services to ensure the smooth and efficient operation of the distribution chain it is critical that the spares are available to issue in the first place. The RAOC attempts to maintain a 95% service level across its complete inventory and this is monitored constantly for fluctuations and variations. The Spares availability achieved by the RAOC is shown at Figure 2.13. It should be noted that since 1980 the Service level has declined dramatically. The overriding reason for this is the cash limiting and moratorium but sharp falls in 81/82, 83/84 and 85/86 are as a result of the Falklands War and 2 major warehouse fires with resulting losses on each occasion in excess of £500 Million.

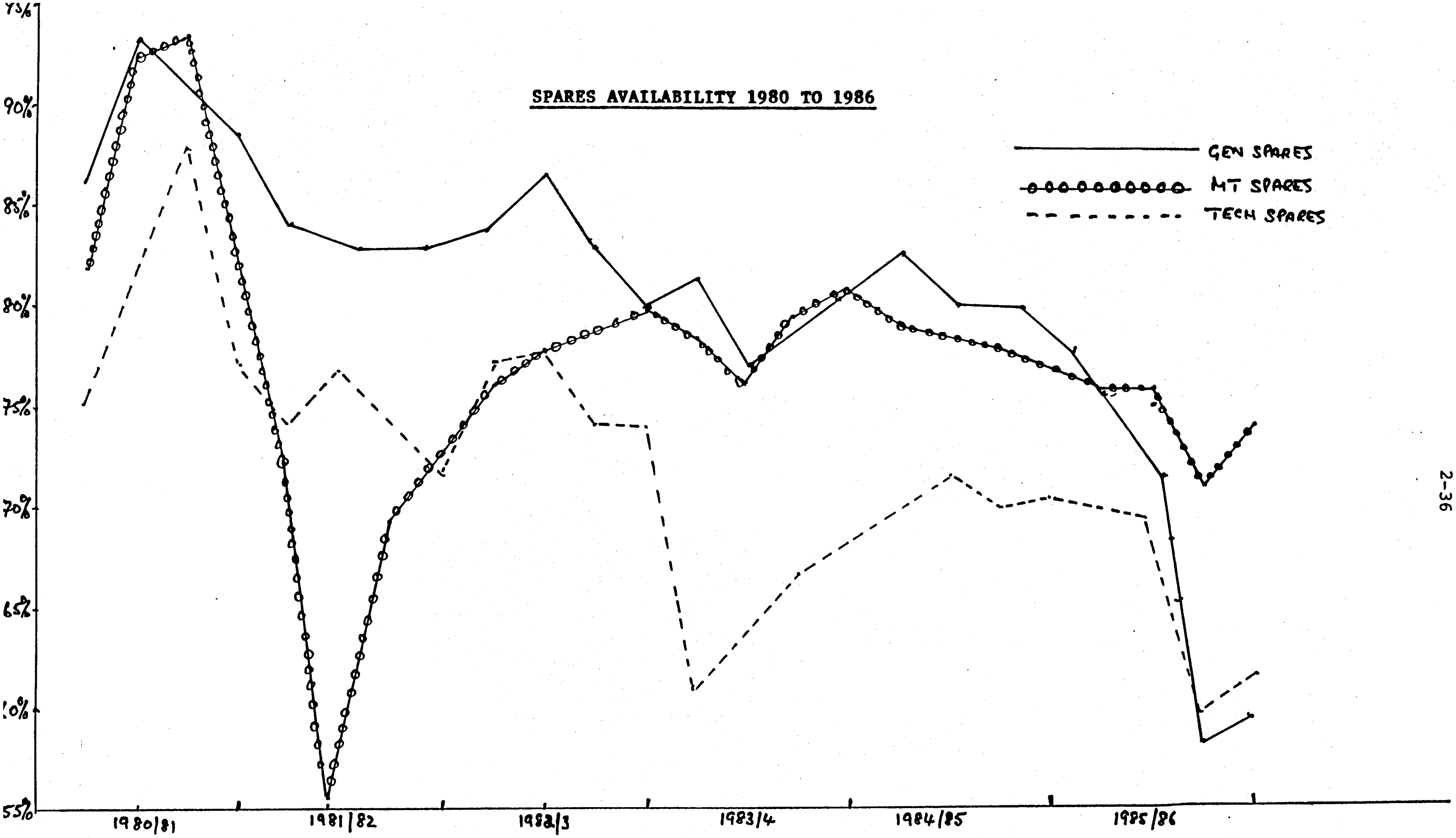

SPARES AVAILABILITY 1980 TO 1986
GEN SPARES
MT SPARES
TECH SPARES
95%
90%
85%
80%
75%
70%
65%
60%
55%
1980/81
1981/82
1982/3
1983/4
1984/85
1985/86

Figure 2-13

WHAT PEOPLE SAY

"Inventory is the money invested in purchasing things that are intended to be resold but have not been resold yet"

CHAPTER 3. LITERATURE SEARCH AND ANALYSIS

INTRODUCTION

3.1. The control of inventory within a military or commercial environment is not new. Ensuring the right item is at the right place in the right quantity has been the aim of every inventory manager almost since inventories were first held. The most striking change in attitude to inventory control has been brought about through the constraint of achieving the aim in the most economic manner. This emphasis on economy has concentrated the minds of both the academic and operational practitioners for the last decade. This attention has culminated in a proliferation of literature on forecasting and stock control within inventory. With the preponderance of material available on the subject of distribution and more in particular on forecasting and stock control any literature search must have an exact and defined aim. This aim was to confirm the basic assumptions of the hypothesis outlined in Chapter 5.

In order to widen the field to encompass the research carried out by other students and bodies the American Defence Logistics Information Exchange Service Centre was accessed and searched for material pertinent to the aim.

The literature search yielded far more material than was initially expected and the main problem encountered was not what to publish or quote or use as reference but what to exclude. Whilst the hypothesis was defined before the literature search was carried out the analysis of the literature was not accomplished by a dogmatic routine. The analysis of the literature for and against the hypothesis allowed the hypothesis to be redefined or restricted. For the purposes of the review and the hypothesis, inventory was not confined to purely the finished goods inventory held by a wholesaler but any literature written on inventory whether it be from a manufacturing, in-process or a finished goods inventory was included. This decision was made as a result of the initial contact with Company A and the knowledge of the RAOC system which led to some doubt as to whether the inventory held by these two was totally commmitted to finished goods or partially based on the requirement to support some form of manufacturing process. (Alternate*)

AIM

3.2 The aim of the literature research/review was to answer the following questions:

a. What is an inventory?

b. Are inventories comparable?

c. What is the purpose of holding inventory?

d. Is inventory policy definable with regard to all inventory?

*As a result of types of available literature the literature search is now contained in both Chapters 3 and 4. The theoretical work is confined mainly to Chapter 3 whilst the more practical approaches are included in Chapter 4.

e. Are constraints on inventory recognisable and visible?

f. What is Customer Service Level.

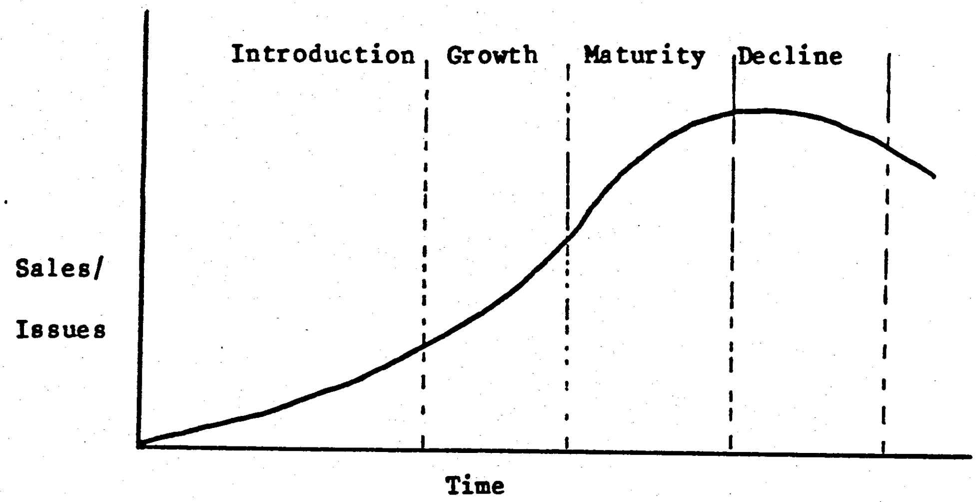
g. What is the measure of effective inventory?

h. Is forecasting possible?

i. Is demand data an accurate base on which to forecast.

WHAT IS AN INVENTORY?

3.3 Engineering branches and Marketing departments would find little fault with a statement that indicated that a spare or a finished product had a life expectancy. This life expectancy would normally be broken down into a launch period, a sales surge or decline and finally, the death or obsolescence of the item. It is a tendency, clearly illustrated by J D Patton 84, to identify animate factors with the items which we hold in inventory. It is however significant that we tend to regard the complete inventory as an inanimate object. The inventory is however built up because of the fact that equipment and spares go through this product life cycle. MacMillan regards the cycle as the very hub of strategic management. By using the standard product life cycle, see Fig 3.1., he argues that the marketing imperatives will vary according to the stage of the life cycle; so too will the return on sales and investment. Converted into Public as opposed to Private terminology the stock holding levels required will vary at each stage. Failure to monitor product life cycles carefully will lead to increasing levels of slow or non moving stock within inventory with no appreciable impact upon operability.



Standard Product Life Cycle

Figure 3.1

The problem of product life stage identification is compounded by the number of differing products an inventory must support. Inventory relating to one type of product tend to be labelled numerically to aid identification. This identification can be negated when groups are made up of items having totally different product life cycles.

The advent of computers with their speed of operation is assisted by the grouping of commodities and the allocation of numbers in some form of sequential allocation. The traditional allocation of numbers has evolved from the parts explosion of the major equipment or an equipment which is allocated to the defined category or group. If the divergence between the A, B and C categories is slight the inventory may be regarded as homogenous. If, however, the divergence ranges from fast moving to totally inactive then the inventory cannot be regarded as homogenous. If homogenity does not exist then the application of standard forecasting and stock control practices across the complete inventory is illogical. The group or groups of items which a company holds may therefore fall into either a homogeneous or non homogeneous life pattern. The nature of the business within which inventory is held will dictate the homogeneity or not of the inventory held.

The more obvious sub division of natures of business in which inventories are held may be high technology, low technology or no technology. The probability of homogeneity is far greater within an inventory in which there is no technology than it is in a high technology group. Within the area of no technology it would be possible to place for example such products as food commodities, clothing, furniture and everyday consumables. In the low technology business area the tendency is for products which although requiring some technology expertise in manufacture are well established and the risk factor of redundancy of stock held is minimal. Redundant or obsolete stock will still be able to be sold as a market place will exist for some time into the future. In both low technology and no technology inventories, demand tends to have stabilised and inventory control and forecasting techniques have a greater probability of success. That is not to say that these techniques are simple or guaranteed to succeed as the movement whether it be fast or slow, and the homogeneity of the groups will dictate the actual success.

Excess inventory or overstocking is not peculiar to any single type of inventory but is an operational risk that must be accepted. "In every inventory there will be some parts that have more stock than is needed. It may be because of production overruns, quantity buys, engineering changes or simply goofs" RG Brown 1982. It is the limitation and identification of the causes not eradication of this problem which should be the focus of management attention. Inventories which draw the majority of their item headings from the high technology parameter of stores, rely heavily on engineering assessments for their future demand and failure patterns. The expected mean time between failures in these high technology areas are balanced against past technology on which experience already exists. The greatest area of risk within inventories must be attributed to the launch or subsequent support of high technology equipments for which there is no past history or failure patterns that can be confirmed. It is evident therefore that after a sub division of technology in relation to product that inventory is held to cater for 2 precise factors. Firstly, to cater for a known or estimated future demand and secondly, for the elimination of possible risk of failure.

Inventories catering for a known or possible future demand will tend to have a high stock turn ratio in relation to the low stock turn ratio of those inventories catering for a high risk environment. The technological aspects of the item headings held within inventory will also in some way dictate the depth of holdings of that inventory. The more technologically orientated the item headings, the less suppliers that there will probably be available to supply the item and the greater the lead time between order and receipt. The depth of inventory that is to be held will be dictated by the reaction time that the inventory must meet to support its customer or the equipments it supports. The lack of technical knowledge by the provisioning clerk, related to specific item headings, will further exacerbate this problem. "One of the biggest single factors that causes technical representatives to stock excess parts is lack of confidence in being resupplied" J D Patton 1984.

ARE INVENTORIES COMPARABLE?

3.4. Modern management tends to evaluate performance across the total company function. Inventories are no exception and many methods are used by different institutions to quantify, whether numerically, physically or financially the effectiveness of the inventory they hold. These analyses result in facts and figures normally expressed in percentages. These percentages are then used to compare the success or failure in relation to other enterprises. Such a comparison of the RAOC inventory with best commercial practice was the stimulus which resulted in this particular research being carried out. One of the hypothesis suggested in Chapter 5 is that inventories are not comparable and the aim of the literature search was to identify what form of analysis were used to interpret the effectiveness of inventory prior to its comparison with the performance of other institutions or bodies.

One of the most critical elements of any comparative process is the assumption that the figures published by a Company are accurate and reflect the true situation. A trade study carried out on a leading Company interpreted the figures by the Company and then researched the data provided by the Company and resulted in a discrepancy of up to 30% between the published figures and the true situation. It is a human failing that we wish to be told not what is actually happening but what we would like to happen and it is a tendency therefore, to interpret figures to produce the facts that we most want to see. This phenomena was noted by D M Lambert who stated "few firms or managers within the firms totally understand the reason why they are carrying inventory. It is therefore extremely difficult for them to set policy decisions by which their inventory will be controlled." R G Brown also hints that this manipulation of figures tells us what we want to know when he says, "let the accountants worry about precision. Accuracy is sufficient of inventory management". The relevance and accuracy of comparison will be affected by the type of inventories that are being compared.

Distortion of numerical analysis in comparisons, is affected by both size and depth of inventory. By size, I am referring to the number of item headings, which are unique, that are held within the inventory. With regard to depth the number of weeks, months or years supply held in stock. The information which is finally produced tends to represent what is believed to be happening as opposed to what is actually happening. In addition, the variance of efficiency will depend upon the size of the population or number of customers to which the depth of inventory is related. P Bailey and D Farmer 1982 noted this disparity of the problem caused by size and dispersion when they attempted to compare W H Smith and other High Street retailers. "In the case of British Home Stores, Marks & Spencer and Mothercare, they are characterised by a relatively small number of product lines, tight margins and high sales per sq foot and a high degree of central control". They argued that W H Smith's problem is far greater "however you will realise that with 300 plus branches and perhaps 60,000 product lines in total, only half of which are supplied centrally, this is no easy matter". If this is now contrasted with the RAOC problem of something in the region of 1000 plus branches and an inventory in the order of 730,000 product lines in total, the dimensions of the problem are perhaps brought into perspective.

Measurements of inventory efficiency produced as management information are widely documented and universally accepted. These are discussed at Paragraph 3.9 and Figure 3.5 details the more widely accepted analysis used.

Whilst the policy decisions set for either dependent or independent demand inventories may be the same, it is argued by D J Bowersox 1978 that their control mechanisms are different. "To help cope with the uncertainty of independent demand, business institutions purchasing for resale typically utilise reorder point inventory control systems.

Unlike the resale situation which was categorized by independent demand the MRP procedure is based upon the assumption of dependent demand". Whilst the actual efficiency of the 2 separate inventories may be the same the control mechanisms which achieves this efficiency would be totally different. If the MRP control system was twice as expensive as the reorder point system, the commercial argument would be that the more efficient of the two was the reorder point control system. This argument is nebulous as the dependent demand item could not adequately be controlled with the reorder point control system, without vast increases in the depth of inventory held and the associated inventory costs incurred.

It is questionable therefore, whether the inventory should be compared to a like dependent inventory or like independent inventory. It is fairly obvious that a dependent inventory should not be compared with an independent inventory. Nearly every document or piece of literature researched dealt with inventory in general terms without being specific. D J Bowersox 1978 stated that "the mission of the logistical system is measured in terms of total cost and performance". All of the comparisons that were investigated and that have been researched, concentrated on the total cost and performance categories with scant if any regard for the actual mission. The mission of the logistical system when translated into economic considerations results in increased or decreased inventory. This overriding constraint on which policy decisions are based precludes comparison between inventories unless the missions are similar or identical. Comparative data only has significance when the overriding constraints and environment within which an inventory is held are identical. When this data can be produced in relation to standard industrial classification, then it is meaningful but it is not necessarily comparable with another institution or bodies results. As an indicative measure of the methods and controls employed by a company, whether it be private or public it serves to highlight either those areas where malpractice is occurring or where policy should be considered carefully to realise economic savings.

Comparisons which express efficiency as a percentage of sales or profit tend to relate to those companies where the customer has a choice about where he procures his product. Thus the customer has the opportunity to choose from where he purchases and is only constrained financially on what he may purchase. Within most public bodies and in particular the RAOC the customer is totally captive, he may not purchase from an alternative source and he may purchase/demand only that to which he is entitled. In order to compare inventories it is essential that the freedom or lack of freedom of the customer is taken into consideration.

3.4.1. Summary. To summarize, the ability to compare inventories is largely dependent upon the following facts being known, accurate, equatable and measurable:

a. Inventory size.

b. Depth of holdings.

c. Demand Pattern Dependant/Independant.

d. Dispersion of stock and customers.

e. Forecasting systems.

f. Mission.

g. Total cost variables.

h. Performance Indicators and Calculations.

i. Constraints.

j. Industrial Classification.

k. Customers (Captive/Free).

WHAT IS THE PURPOSE OF HOLDING INVENTORY?

3.5 Few if any authors when writing on distribution actually pay attention to the reason for holding inventory. Generally speaking they tend to automatically accept that inventory is required and should be held at various stages throughout the enterprise or business. When the problem is addressed the tendency appears to be that ambiguous statements are used to overcome the problem of actually quantifying the reasons why inventory is held. Policy within companies should clearly state the purpose for which inventory is held.

The requirements to hold inventory are viewed differently by each hierarchical level of management. E W Smykay 1973 identifies the two extremes quite clearly "On the macro level, the inventory volume is a measure of the investment required to maintain gross national economic activity. On the micro level, it not only measures necessary resource commitment but also provides a tool for achieving broader corporate objectives." If corporate objectives can be achieved by holding zero inventory or these objectives are only very partially limited by holding zero inventory, then there is no reason to hold any inventory at all. Inventory is normally held to limit the risk which a company would be faced with if no inventory were held. This risk is generally allied to the effect upon profit, loss or reduction in operational efficiency. Bowersox (1978) was quite clear about this problem when he wrote "inventory is one of the riskiest decision areas in logistical management. Commitment to a particular inventory assortment and subsequent market allocation in anticipation of future sales represents the vortex of logistical operations". R G Brown (1982) also seems to confirm this concept when he writes "uncertainty about parts translates into inventory". The purpose therefore of inventory may be deduced as an attempt to eliminate uncertainty or risk about those parts or the stock that we hold for our customers. The risk translates into inventory and here, yet again the mistake of having a single inventory appears to have been made. This risk even if it is actually quantified is applied against all inventory regardless of the risk involved item heading by item heading. J D Patton (1984) extrapolated the concept of risk to measure the effectiveness of the inventory "risk can be measured as the percent of orders not filled within the specified time limit. Risk is a fact of life with service parts." With regard to the concept of complete inventory what he is doing is quantifying not what the risk is but what the acceptable risk is likely to be. However this takes no account of the criticality of those items within the inventory. Perhaps a clear illustration of risk is an example drawn from the airline industry. A new engine was required to be fitted to an aircraft. The engine was available from within the inventory but the bolts were not. The risk of stockout for an engine was regarded as having more detrimental effect to the company than the risk of a bolt being out of stock. If it is possible to quantify the risk per item heading within the inventory, it would be possible to decide the element of risk that could be taken with each part with regard to stockout. This is perhaps a key area where the civilian institutions, whether public or private differ from the military inventory. The most disastrous effect of a stockout within the civilian environment will be a loss of profit or a reduction in operational capability. The most extreme effect of stockout within the military environment is death of an individual or in the most extreme case the defeat of an army.

It would be acceptable therefore to compare the commercial systems whether public or private with the military systems if they were only geared to supply the army in peace. The additional inventory required to decrease the probability of stockout means that the military system is carrying a greater depth of stock than its commercial counterpart.

Failure (stock out) will still occur however and this fact must be accepted and not used as a lever to further increase stock holding. Regardless of the level of stock held F R Johnston 1980 states "Because the future is uncertain any (reasonable) amount of stock may in the event prove to be insufficient to meet demand".

IS INVENTORY POLICY DEFINABLE WITH REGARD TO ALL INVENTORY?

3.6 It is dereguer for todays manager to involve himself in finance whilst failing to issue Policy. ME Cook and K Muinch 1983 sum up this problem quite clearly "In most companies there is no formal plan developed. The financial management generally edicts some budget for overall inventories". Whilst not the overriding motivator money seems to generate far greater interest than service. The actual cost of holding and buying inventory are still being debated but even by using the simplest calculations the costs are significant. The modern businessman/manager expects a return on his investment. Distribution costs are often expressed as a percentage of the total turnover and tend to be a cost adding as opposed to a profit earning element. Failure to define clear policy which is measurable and planned will lead to financial cuts being imposed. D M Lambert 1975 was extremely scathing about this degree of planning "Few firms or managers within firms totally understand the actual reason why they are carrying inventory. It is therefore extremely difficult for them to set policy decisions by which their inventory will be controlled".

Inventory policy whether it be defined in order to achieve objectives is dependent upon the hierarchial structure of the company involved. To be practical and usable for the inventory manager it must be clear and overt, however within the business environment overt policy is a tool which may be utilised by the competitors within the field. The tendency therefore is to have covert policy which is only defined within the business structure and is not freely available to external bodies. Hierarchial structures whether they be vertically or horizontally aligned tend to lead to multiple policy decisions. This multiplicity of policy variables leads to inefficiencies in inventory forecasting and control. Inventory policy to be effective must be reactive to both internal and external variables.

ARE CONSTRAINTS ON INVENTORY RECOGNISABLE AND VISIBLE?

3.7 The ambition of the inventory manager is to ensure that the right item is always held and is always available to the customer. None of the literature researched or any of the companies visited ever talked about all items. It follows therefore that the inventory is not there to provide everything for everyone but the majority of items for a selected field of customers. It is these customers requirements whether based on market research or the analysis of past demands that should decide what is to be held within the inventory and dictate the constraints upon the size and depth of the inventory. E W Smykay 1973 supports this argument when he says "although customers may be controlled to some degree, the most critical factors in inventory systems, that is, the time and quantity of demand for the firms product are largely controlled by them".

The first identifiable constraint should therefore be drawn from the customers which the organization wishes to serve. The number and frequency of the demands from these customers and the profit or lost potential of not stocking these parts will dictate whether or not that item should be held within the inventory. This particular constraint however can be actual or perceived. The 'actual' will be inventory that is stocked because of known past/future demands and perceived will be inventory which is stocked in anticipation of receiving customer orders for such a part number.

The second major constraint which is identified quite clearly and is also applicable to nearly every form of inventory is the problem with purchasing the correct quantities required to be stocked. Normally the depth of individual item heading holdings will be dictated by the availability from the manufacturer or wholesaler. The effects on depth however are not purely dictated by the wholesaler or manufacturer but by the perceptions of the economy achievable within the procurement cycle. In addition there may be some agreed policy within the company to hold maximum/minimum stock levels in anticipation of future demands or in order to safeguard emergency operations.

The more obvious and visible constraints on inventory are normally allied to finance. These can be broken down into the elements of the FW Harris EOQ formula and are cost to hold, cost to order and the cost of stock. Recent literature and the modern manager concentrate large amounts of their time on these economic considerations. Whilst they are visible and tangible they are often impossible to accurately define. Zanakis et al 1980 would in fact go further "The thorn of cost estimation in inventory control continues to aggravate users of inventory models. There is no uniform agreement on how these costs should be estimated. Even within a single organisation, one is unlikely to find two accountants who will agree completely". Within the inventory itself there is no problem with identifying the cost of an item that moves on a regular basis as the charge will be costed at the latest price paid, assuming the company works on a first in first out principle. However the cost or price that the company should rate itself for an item that is held in stock for several years is extremely difficult to calculate, often, that particular commodity will be worth either far more or far less than its initial purchase price. It is therefore difficult for the company to accurately account for the actual cost of the inventory held.

To illustrate the accountants dilemma further it is worth examining one single human input to the cost to order function of the EOQ formula. A provision clerk may end up carrying out the following duties:

Provision Clerk ____________ Customer feedback, Ordering, stock control, Issue processing, Demand experience, Hastening.

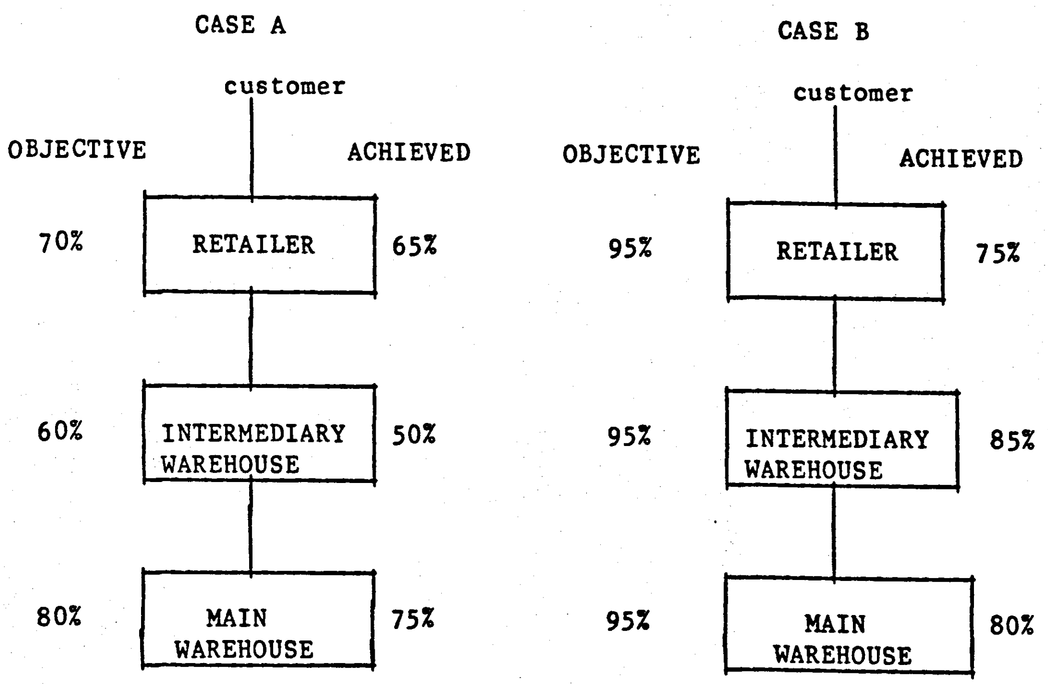
These are just a few of the functions carried out by a provision clerk within a company. The degree of constraint placed upon the inventory will depend upon whether the complete wages of the clerk, the space she occupies, the accommodation and support she requires are charged against the inventory or against the overheads of the business. If they are charged against the inventory they are a visible, perhaps unjustified constraint, but if they are charged against the company they are an invisible cost of carrying inventory.

The more readily visible constraints on inventory are, or should be, laid down by management in their policy objectives. These directives range from limiting the powers of purchase of individuals in specific areas to limiting the physical quantity of stock which may be procured or alternatively the budget estimates are constrained over the time period for which stock should be held. These are just a few of the many examples that could be drawn on policy objectives that are laid down by management and are sanctioned across the whole inventory with scant regard for particular groupings, categories or specific special cases.

WHAT IS CUSTOMER SERVICE LEVEL

3.8 Where a Policy objective may be regarded as tangible it is theoretically possible to measure the degree to which this objective is successfully achieved. There is an old saying, used when asked to quantify some intangible, that evades the issue by saying how long is a piece of string. This saying epitomises the problem faced by most distribution managers. Definitions of inventory may be related to the definition of physical distribution in that the start and finish points which should be considered for inclusion are elusive. The term inventory is loosely used to cover any form of stock held to meet a future (customer) need. The stock may therefore be in a raw, semi-finished, finished, component or complete equipment state and it may be made, assembled or simply bought by the company. The stock may pass through several intermediary integral levels of a company before it arrives with a customer or at its first move may be used and consumed by the customer or it may form part of an inventory held by the customer. Whilst the expansion of start and finish points of measurement can be taken to great lengths most companies accept that the inventory should be measured with regard to the stock level held and the customer service level achieved. The majority, and all of those companies who participated were adamant that, the customer service level which the customer required and not necessarily that perceived by the company was the most overriding measure of effective inventory. The byline of one company supports this argument in that they believe that "marketing sell the first machine, customer service of spares sells the second".

The service level given to customers is rated against the number of demands placed and those met within a given timescale. The more general methods of calculation are covered by Christopher 85. There is however a very serious dichotomy which most analysts of efficiency of inventory evade. Most service or public inventories support captive customers whereas private enterprise tend to support free customers. There are no lost sales when the customer is captive just complaints or delays, both of which are used as cudgels to beat the inventory managers. The public inventory manager can therefore record his actual service level at the branch (Ordnance Company) and customer (unit) level. This is not the case in private enterprise under most circumstances. P Bailey and D Farmer 1982 "One very real problem is that we know a good deal less about the service levels between the branch and the customer". Private enterprise with free customers has no way of measuring lost sales and this is perhaps the most difficult area for private companies without captive customers to quantify. If therefore failure cannot be quantified then how can the level of success be measured accurately. The majority of companies if asked their service level will state their objective at x% and their achieved level at x-n%. Comparison of the set objective and that achieved by companies does not always elude to a fair comparison of efficiency. The majority of companies included in the study have more than two levels at which inventory is held and it was fairly evident at an early stage that there was no standard by which service level was calculated. The two main methods are illustrated below:



Customer Service Calculation

Figure 3.2

In Case A the company aims to meet 70 out of 100 demands at the retailer, 60% of 30 demands at the intermediary and 80% of the 12 demands which arrive at the main warehouse. The objective service level is therefore 97.6% and the achieved, using the same method of calculation is 95.7%.

In Case B the company aims to meet 95% of all demands at each level but based on the receipt of 100 demands. Its objective is 95% but its achieved, using the same method of calculation, is 80%. Case B concentrates not on the service level to the customer but the service level between each element of the distribution chain. Case B therefore allows the relative efficiency of each stage of inventory to be calculated. If however the service level for Case B is calculated using Case A formulae then the actual service level achieved is 99.25%.

These figures would be acceptable in either case as a true accurate measurement, if the recorded figures at the retail point relate to captive customers. If the customers are free then the number of actual demands placed on the system is often unknown. For comparative purposes between companies it would only be acceptable to compare service levels achieved if the system and methods of calculation used are identical. Service level whilst being of vital importance to stock levels and monitoring systems does not measure the effectiveness of inventory for comparative performance. This is quite forcefully put by E Landou 79 when he stated that "If we examine the trade-off between investment and service for an entire inventory, instead of for a single product, we find that there is no longer a direct relationship".

The Public accounts committees suggests that the RAOC examine best commercial practice because in comparison it is better. If the customer service level and the customer expectations differ between companies then it is also true to state that the Policy and doctrine laid down to operate the system and meet the customer needs are also different. If as is argued in paragraph 3.6 Policy is laid down dependent upon the type of inventory and the customer needs, then measures of effectiveness are rated against the company Policy. To illustrate this point company B's, inventory is held to support flying operations. They had held for several years 12 nosecones for their Viscount fleet. There had been no issues for 4 years. In one day hailstones pierced 11 nose cones. Efficient inventories it may be argued would have disposed of slow moving/dead stock and improved their stock turn ration with no adverse affect on their customer. Until the day, that is, when the spare is required and it is not available.

A parallel between the peace and war dilemma faced by the RAOC can be drawn from this case in that the efficiency of the inventory cannot be calculated until the premise for which it is held occurs. Regrettably that is war. In a similar way companies B and C also hold stock to support rescue operations/activities after a disaster/accident. The movement of spares is zero until the point in time when the accident/disaster occurs. If the scale of the anticipated disaster and war were equatable then it might be possible to measure the efficiency of these inventories and then compare performance.

WHAT IS THE MEASURE OF EFFECTIVE INVENTORY

3.9 The measurement of effective inventory must be viewed from at least three perspectives. An inventory continually strives to achieve more than one aim. Perhaps the greatest importance is the user of the inventory (the Customer) and at the other end of the spectrum is the owner of the Inventory who may be one or more stages removed from it. Somewhere in the middle of the two is the inventory manager who must put into operation the wishes of these two whilst meeting their conflicting requirements. No single measurement to deduce the effectiveness of inventory exists. This is probably due to the fact that few inventories operate under identical circumstances or with the same constraints. Ten methods which can be used are summarised at Fig 3.5. Some of these methods are covered by various authors, most of whom differ in how they should be implemented, others are regarded as general practice within distribution systems and are not documented. They are covered, not to show what should be done but, to illustrate the divergence of opinion, documented in Chapter 4, of what effective inventory means to different types of inventory.

3.9.1 ABC. Management of stock is time consuming. Time costs money and most managers will therefore attempt some form of segregation to allow the focus of attention to fall on those items considered most important. This type of analysis is often very crude and the results change from period to period. Based upon the Pareto 80/20 theory which is applicable to many inventories after certain caveats (*Note 1) have been applied. There are two forms of analysis, ABC Throughput and ABC Value Throughput.

Note 1. If all non-moving stock is disregarded totally within an inventory 20% of all issues account for 80% of demand.

3.9.1.1 ABC Throughput. This analysis is only applied to the quantitive number of units sold/issued/demanded in the time period under review. It clearly identifies where the movement of stock is taking place. It is however easily manipulated or affected by pack size or units of account, shelf life, seasonality and durability of product. There is a tendency for a blurring of the B Category within A and C and the tendency is for the B to be absorbed into A leaving just A and C categories.

3.9.1.2. ABC Value Throughput. Perhaps the most widely used analysis within the distribution field. By multiplying the throughput by the value ABC ranking is much more effective. Management time is concentrated on those areas where the majority of the capital is being expended. By the addition of a stock times cost column the inventory can be pared to a minimum stock holding level whilst maintaining an acceptable Customer Service Level. It requires a rapid form of analysis carried out on a regular basis. The larger the inventory becomes the more unwieldy the data is and analysis tends to be carried out less frequently. The data represents a historical snapshot and is not an indication of future sales or demands. Background information on each product is required before inventory planning decisions can be made. The analysis does however offer a means of establishing how well the inventory is being controlled. It can be distorted by external constraints which if not clearly identified will lead to incorrect assumptions being made.

3.9.2. Stock Turn. The stock turn is normally taken as the ratio of annual sales/issues turnover to average stock levels. The stock turn is used to give a measure of how efficiently companies are employing their stocks. Figure 3.3 shows 5 groups of companies min and max stock turns.

	Food Drink and Tobacco	Chemicals and Allied Products	Electrical Engineering	Textiles and Clothing	Distribution Trades
Min	1.4	2.4	4.0	2.3	3.1
Avg	10.4	14.7	5.2	10.4	14.4
Max	27.6	75.0	6.3	21.1	30.9

Stock Turn Table

Figure 3.3

Reproduced from Survey of Distribution Costs Centre for Physical Distribution Management 1984.

This analysis when compared with other companies indicates whether the inventory is Active or Passive. It is a clear indication of the use of capital and shows whether or not defined Policy is being implemented. It can be used in conjunction with the depth of stock analysis to ascertain the percentage of inventory not under control. The RAOC inventory and 2 of the participating Companies achieved a stock turn of ½ and would not have been included in the categories displayed in Figure 3.3.

3.9.3. Service Level. The setting of Service Level is always a Policy decision therefore the analysis of the performance of the whole inventory or segments of inventory to meet laid down policy is often carried out. The analysis can however be totally meaningless or counter productive. Service Levels are often laid down for inventory in a blanket fashion with little or no thought. Much work and study has gone into Customer Service and the effects of lowering Service Level and the subject is surrounded with a certain mystique. There are two points which should be noted. Firstly the only person who understands what he wants is the customer and secondly the best system in the world is not foolproof. Any attempt to increase service level will involve increased cost and normally increase stock holding. For true service level covering the period from raising to meeting a demand too many agencies are involved to ensure credibility of figures. The analysis is always prone to manipulation and there is no safe method of checking accuracy.

3.9.4. Stock Out/Back Orders. Customers are the life blood of any inventory and failure to supply, whether total or within the quoted time frame, is one of the predominant ongoing analyses within any company. Statistical presentation of the failure is insufficient to deduce whether or not the inventory is meeting the constraints or demands of Policy. It is necessary to investigate each and every failure to ascertain the primal cause of failure in order that modification to the system can be implemented. A rising stock out rate can be indicative of many external factors and should not be used in the first instance to level accusations of inadequacy. The most frequent stockouts should occur in the product launch or product decline phase but only careful investigation of both Policy and cause will ascertain the real reason. Within the automotive field for example a customer will wait for many months for a Jaguar or Morgan but expect almost instant delivery for a Metro or Cavalier. Similar comparisons should be drawn for complex and simple spares held within Inventory. A Policy decision stating that buffer stocks will increase when X percent stockouts occur is nugatory. Stockouts are vulnerable to chain reactions from manufacturers and suppliers and to customers whims and wishes in fashion vogue, and seasonality. As a barometer to implement positive action the stockout analysis is useful but should be treated with care.

3.9.5. Customer Complaints. Verbal or written complaints receive differing degrees of attention dependent on who makes them (the status of the customer) and who receives them (the status of the individual). Any member of a company not involved with inventory is unable to comprehend why 'Storespeople' cannot get their act together. Ideally customer complaints should be properly tabulated, each one receiving preferential treatment albeit only a letter, and when a trend becomes visible effective action to change the system or the Policy should be taken. Inventory management effort is often needlessly wasted preparing historical background to placate a supposedly irate customer or defend inventory Policy when their time would be better employed resolving real inventory problems.

3.9.6. ROCE. Return on Capital employed is largely only usable when the inventory interfaces directly with a cash paying customer. When this is the case the first difficulty is deducing what elements represent the output and the second is normally who really generates the input. Marketing would always argue that their effort produces the main input but dislike their overheads/budget being controlled by the inventory budget. If inventory is the sole profit earning element within a company roce analysis is an invaluable tool. Its best effect is to identify within the inventory those items which generate most profit. This allows the focus of managerial effort to stay with those items. When inventory is one element of a larger conglomerate contribution to overall profit and the share of costs may be disproportionate and roce becomes in this instance less effective. Where an inventory is used in a support or service mode to a profit earning area then investment returns from inventory are even more difficult to calculate. It is often easier to combine two support activities in this instance to give a cost to maintain a unit of equipment. Without some form of financial comparison the inventory will be unable to justify its actions or fight for coherent Policy. It becomes a financiers budget target and the output damage may not be evident until the damage is irreparable.

3.9.7. Inventory Costs as % of Sales. Inventory or distribution costs are generally taken to be those costs covering Storage, Inventory, Transport and Administration. Each company will have its own views on what costs are included but if comparison is considered these costs should be clearly defined especially in the administration, building and stock depreciation areas. Preparation of such an analysis leads to a clearer understanding of Fixed and Variable overheads within distribution and enable more effective decision making. Normally this analysis leads to a progressive reduction in direct labour but in addition warehouse space and stock levels can often be optimised. The Centre for Physical Distribution Management argue that the magnitude of a company's distribution cost to sales ratio, does not necessarily reflect the true importance of the distribution operation as a profit generator. A more important measure is the distribution cost to profit ratio. The higher the ratio, the greater the impact that even minor changes of the distribution cost profile will have on a company's profit performance. The table at Fig 3.4 shows the Inventory cost as % of sales in 5 categories. The RAOC and Thesis Companies all had an

	Food Drink and Tobacco	Chemicals and Allied Products	Electrical Engineering	Textiles and Clothing	Distribution Trades
Min	0.91	1.93	5.51	1.16	0.48
Avg	13.37	6.23	14.49	8.22	11.46
Max	20.37	15.7	23.48	18.38	32.33

Inventory cost as % of Sales

Figure 3.4

Reproduced from Survey of Distribution Costs Centre for Physical Distribution Management 1984.

Inventory cost as % of Sales in the Maximum bracket 20 to 28. The large % of slow or non moving inventory, held to minimise risk, face even the so called 'best commercial practice' companies into the maximum ratio area.

<u>3.9.8. Depth of Stock v Policy</u>. This is one of the simplest stock analyses to carry out but it normally produces the wrong effect if unsupported by documentary data. The analysis is quick and crude, provision of the documentary support is often time consuming and often unavailable due to the passage of time. Simply dividing stock on hand by period usage will give the weeks, months or years of stock held within inventory. Carried out regularly it allows stockouts to be prevented by timely action and that is its main use. It should however be used for two other checks as well. Company policy should state a maximum and minimum stock which should be held. Normally only the less than minimum area receives attention. Excess stock holdings should be as vigourously analysed as shortage of stock. It can also be used to check the excessive zeal of procurement departments who at times ignore the formula, calculations and policy because they are privy to information no one else possesses. This analysis therefore is of benefit to both inventory and procurement departments.

<u>3.9.9. Forecasting Accuracy</u>. Forecasting is at worst a guess and at best a calculated gamble. A marksman when he fires a shot will find out how much he missed by, alter his sights and repeat this process until he hits the target. If he fails to hit the target he may change his rifle or ammunition or practice more. The accuracy of most forecasting models is too infrequently assessed or checked but the inaccuracy can be ascertained from the overstocking and understocking

within inventories. Practitioners and systems managers appear unaware of the different forecasting models available to them and are prevented by cost from implementing alternative solutions. Each firm tends to have two forecasting systems, the calculated one in the computer and the human generated one after the machine has finished. Few companies assess their forecasting accuracy and only the large conglomerates run simulation models to constantly check and practice their system. Forecasting inaccuracies which are understock are highlighted by the customer very quickly. Over forecasting tends today to be absorbed into the inventory. It can easily be spotted by a depth of stock policy but this is often too late. Forecasting accuracy checks should be run on a regular basis if stock levels are to be maintained correctly.

MEASURES OF EFFECTIVE INVENTORY

Serial	Analysic	Effect	Use	Remarks
(a)	(b)	(c)	(d)	(e)
1	ABC Throughput	Categories Movement	Concentrates Resource effect	Variation between categories can be significant/ insignificant
2	ABC Value Throughput	Categories Capital Employed	Concentrates Management effort	Generally represents minute preparation of item headings
3	Stock turn	Deduces Active Passive Inventory	Comparison with like Inventory	An indicator of use of capital
4	Service Level	Increases Inventory	Controls Availability	Difficulty in measurement between Captive/Free customers
5	Stock Out Back Orders	Indicates poor control	Yardstick for inventory holdings	Affected by seasonal demand and supplier failure
6	Customer Complaints	Dependant on status of Customer	Various	Often depends upon acceptance of complaint
7	ROCE	Decreases Stock Levels	Monitors employment of capital	Only effective where profit is generated
8	Inventory Costs as % of Sales	Decreases Labour element	Moniters employment of labour	Depends upon interpretation of cost parameters. Easily manipulated
9	Depth of Stock V Policy	Limits Stock Holdings	Control Purchasing Element	Policy is normally ambiguous
10	Forecasting Accuracy	Decreases/ Increases Stock levels	Control Stock Levels	Most models tend to monitor under not over forecasting

Figure 3.5

Note: Figure summarises paras 3.9.1 to 3.9.9 and completes description contained in para 3.9 (page 3.25).

IS FORECASTING POSSIBLE?

3.10. Forecasting by its very definition is a prediction or calculation in advance of an event happening and by its very nature must be assumed to contain a degree of inaccuracy. Forecasting is at best an art which may be improved by the application of science or clear methodology. Most authors agreed with this format or definition albeit with differing words. J Gattorna 1986 simplifies the complete statement even further "What happened last week, or last year, provides no guarantee of what may happen now or tomorrow". All the literature researched covering forecasting, whether briefly in a few pages or in great depth, tended to make generalised assumptions about the type of inventory with which their forecasting model or models would deal.

The most recurring assumption which is apparent in all literature and especially in System Paper 29 is that past demand history would be representative of future demand. This assumption contained one futher element which relied on the variability of demand conforming to the normal distribution curve. This simplex approach to forecasting is regrettably still very much the state of the art technology in use today or in some companies state of the art for tomorrow! The greatest failing of this approach to forecasting is for new or old items. R H Hollier in a paper addressing these two particular problems stated "In a distribution context, problems occur particularly during the introduction of a new product when there is little service data available, or the phasing out of an old product where spares have to be provided for the expected consumption life of the product".

In order to assess the state of the art twenty Companies specialising in Logistics Software were written to and asked what forecasting models were contained within their packages. All replied that no forecasting model was put in but the bespoke system already operated by the company would be programmed into the package on implementation. All of the companies with which this thesis has dealt are still using a form of exponential smoothing which depends upon the assumption of normality past and future and conformity to the standard distribution curve.

The tacit acceptance by the distribution professional whether he be from a public or a private concern of the efficiency of a forecasting system based on past demand is incomprehensible. It must be assumed that the distribution manager believes he is in control or has control over the situation. This is invariably incorrect and as O W Wight 1974 states "Forecasting is like aiming a gun; the further away from the target one stands the less accurate one is likely to be". The key to this acceptance however may be gauged from the comprehension of the inventory that is held and the visibility of the problems discussed in paragraph 3.4.

Little of the literature researched admitted that the inventories which they were discussing were perfect and homogeneous but all in some way or another devise systems by which the variability from the norm could be removed in order that the inventory again became uniform. The most documented element which is removed constantly is seasonality and most items according to the literature search, once seasonality have been removed, return to uniformity and are adequately forecast using the standard distribution curve. Certain authors and companies were still not happy with the simplicity of their forecasting models or in fact the accuracy of their systems. The extremes that companies go to can best be illustrated by O W Wight 1974. "As a result, we frequently see techniques of little significance, like linear programming, refined, re-refined, and mountains of literature written on a subject that really has very limited application". In addition companies have tended to build in increasing complexity in the models that they use to cater for:

a. Marketing feedback.

b. Operational research.

c. Technical engineering data.

d. Customer survey.

e. Environmental changes.

f. Changing trends in:

(1) Economy or GDP.

(2) Life styles.

The increasingly complex models have however not been aimed at individual groups of items but against total inventories. D Swann 1984 sums up the resultant effect adequately "An unsophicticated technique used properly will yield better results than a sophisticated technique used poorly".

IS DEMAND DATA AN ACCURATE BASE ON WHICH TO FORECAST

3.11. The customer whether he be a civilian in the street or a fighting soldier in the field has little if any interest in the problems of the supply system on which he depends. As long as the materiel he requires is available when and where he wants it in order for him to continue operations then all well and good. To expect him to manage his demands on the supply system in order to generate a stable even take-off of stock is to ask the impossible. As a service industry we must expect to react to the whims and wishes of our customers. In order to attempt to even out our demand patterns the supply agencies will offer more favourable terms of payment or quantity discounts during recognised slack periods. Regrettably those inducements are only possible where an element of profit or financial flow is involved. It must be accepted that those companies who operate in the distribution field to earn direct profit may if they so wish, via special offers, influence the buying or consumption patterns of the customers they serve. They are therefore in a position to materially influence their demand patterns in order for them to meet the forecasting model they employ. The efficiency of the model is therefore partly reliant on the marketing policy and partly on the customers needs.

Whilst this element of literature search is well covered the arguments can be biaised either way. "Has the ability" does not mean tht 100 percent success is guaranteed. An example of the principle is the reduction in coal prices during the summer months in order to even out demand versus production.

For those companies operating in a closed/non profit environment whether in the public service or in support of equipments or operations in the private sector this influence on demand is denied. Whilst they are able to predict those months when demand will be greater they are unable to move or temper the effect on their stock levels. Reactive forecasting models will immediately increase the stock levels at the exact point in time when they are least required. The normal distribution answer to this scenario is seasonality but it is not seasonality that is being discussed. Seasonality is a known increase at a particular time of the year for a particular product or product range eg Easter Eggs.

Whilst the time or times of year can be accurately predicted and the volume of demands is generally of the same scale the product or product range required will be dependent on some outside factor or variable which is unknown. Within the military environment there are

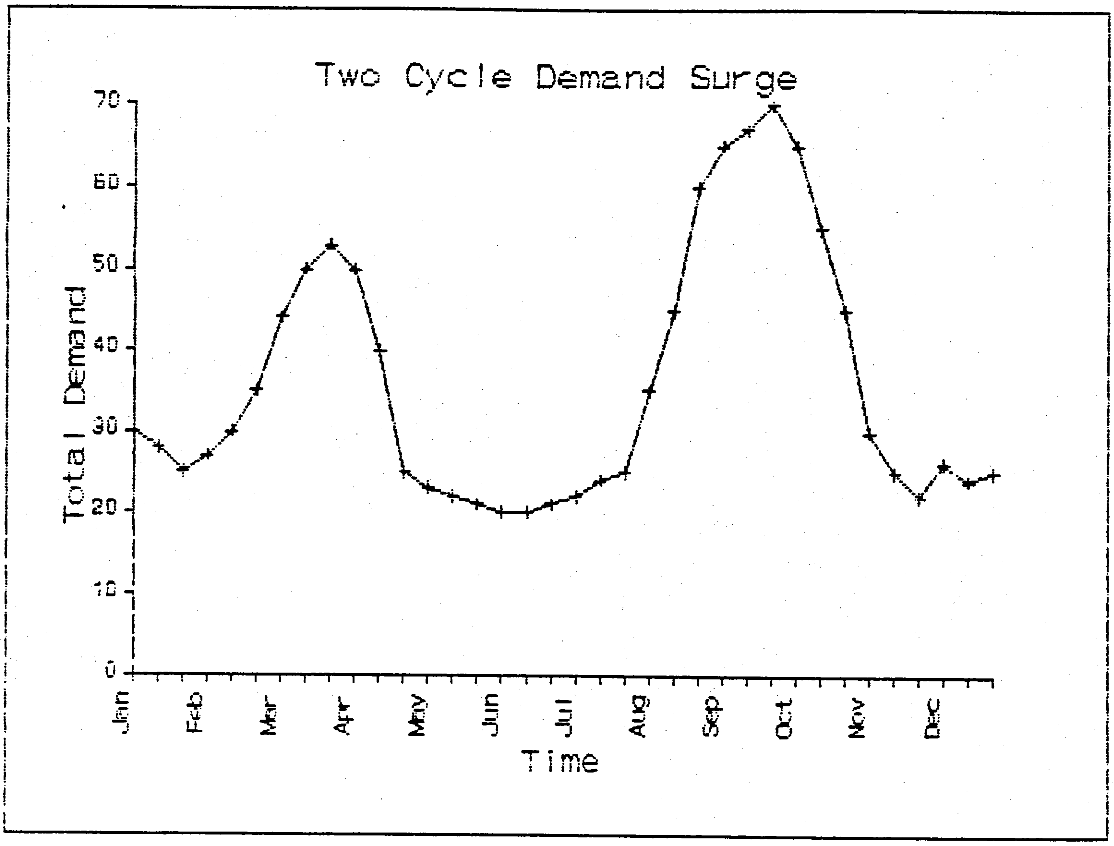


Figure 3-6

two demand surges per year. These surges correspond to known predictable events. The first which occurs in February/March corresponds to the major inspection period when Units (customers) are assessed on their ability to carry out their role. All equipments and troops are brought up to the highest state of operational and military standards. The second period corresponds with the annual major exercises in both UK and BAOR.

This bi-annual 'seasonal' surge is clearly shown from the demand peaks in Figure 3-6. These demand surges occur at the same period each year but for different NSNs. The equipment and spares usage will be dictated by the scenario being played, the total number of troops, the weather conditions and many other variables. It is not possible to predict what items will receive the greatest usage or damage. Although the time of the two surges can be identified the items required to meet the demand vary from year to year. A similar, if not identical problem is faced by the National Health Service. The number of illnesses increases with severe changes in the weather but the type of illness is dependent on the strains of bacteria which have spread and multiplied. The pharmaceutical products required are dependent not on the number of casualties but on what they are suffering from. A greater risk of stockout will occur during these situations and it is quite normal, from the military data, for demands to exceed 3 standard deviations during these periods. The forecasting model described in Chapter Two will adjust the FQD upwards to track this demand which may never recur or if it does will not recur in a seasonal format. The cost to hold variable of the EOQ formula is based upon steady in and out flow of stock. Under the above conditions the cost to hold variable is artificially increased and the EOQ formula partially if not totally negated.

The problem is further exacerbated by the existing policy which allows units (customers) to carry 30 days worth of stock. The rapid consumption of stock during these periods is not presently matched with a communication system which will allow this drain on resources to be identified at an early stage. Stock at the unit may be equated to the stock held by a high street subsidiary outlet and similar to commercal concerns the daily or hourly stock levels are not visible to the distribution system. This problem which is not peculiar to the military is being addressed by Point of Sale (usage) technology and within the next few years may be overcome. The increased speed of communication and demand data does not however solve the problems but produces a better awareness of stock usage. To be totally effective from a TDC viewpoint the complete system must be adjusted to allow the replenishment at the base level at which stock is held to be accomplished at a greater speed. The present military administrative lead time of between 3 and 6 months would be unable to cope. Semi-instant usage/demand data would allow the system to move closer to a KANBAN/just in time form of stock replenishment but would require a complete overhaul of the financial and procurement systems operated within the MOD.

WHAT PEOPLE DO

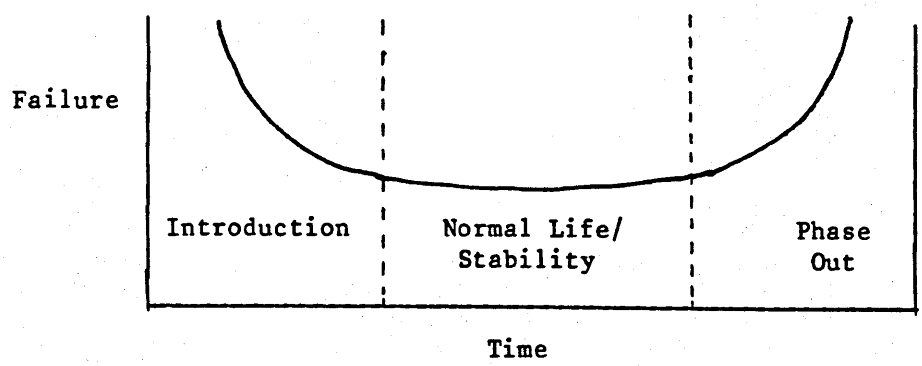
CHAPTER 4A. AVAILABLE AND ALTERNATIVE SYSTEMS

4.1 Introduction

In Chapter 3 real life constraints and working conditions have been ignored. All of the work referred to was manuscript albeit with some case studies. This Chapter will concentrate on real operating systems. These systems have been chosen because of their supposed similarity of use of formulae or operating conditions. More than those companies covered were approached, many were uninterested and did not wish to take part, some offers of assistance were not taken up because of time and distance. Certain 'visits' were via air mail only due to lack of funds. The first 2 paragraphs, 4.2 and 4.3, cover methods and systems generally used in distribution companies today. The third paragraph 4.4 discusses and compares the RAOC and study company systems. The latter paragraphs cover each of the study companies in greater detail.

4.2 Categorisation of Inventory

The variation of demand for spares during an equipments life can never be accurately forecast. This is a deliberate statement which is totally opposite to the normal starting point of any attempt to forecast or control inventory. It is not an admission of defeat but rather a practical as opposed to a theoretical approach to the problem. The more normal approach is to assume that past and future demand will remain constant and that the parts used will be consistent with a normal standard distribution. The theoretical approach caters adequately for only one period during an equipments life and that is normally the mid point. It is an accepted fact that for equipments there are phases of life when the requirement for spares or the item will vary widely. There are differing views on when life starts and when life should end. The most basic subdivision is introduction, stability and phase out. J D Patton subdivides these periods even further into preproduction, product introduction, normal life phase, post production and termination. If the correlation of the usage of spares against the progression of time is accepted then the subdivision of the bath tub curve must illustrate the absurdity of the standard approach to forecasting and inventory control.



Bath Tub Curve

Figure 4-1

Any inventory be it small or large will contain item headings which perform in totally different ways. The rate of their usage will depend on where they are used and what they are used for and who uses them. For example the life of a paint brush can range from a single use to many years life dependent upon the care of the operative. A radio antenna's life may depend on whether it is used by a recruit or a trained soldier. Both items may have differing life spans when used in a hot or a cold climate. The larger the dependency of customers the greater the possible variation in use. Prior to assessing forecasting and control techniques it is therefore important to examine what categories exist within inventories and should any differentiation be applied to these categories.

Technology may often change our future but the historical past will often influence the effect of Technology on the systems we operate. It is now widely recognised that transferring manual inventory systems directly onto Computer systems precludes the potential benefits of computer technology. This area was discussed in paragraph 2.3 Chapter 2. Inventory practice has been, and still is today, prone to subdivide inventory into like item related components and then sequentially number them, often with a master identifying number or alphabetic classification. This standard practice facilitates procurement procedures and enables related item groups to be considered for purchase to ensure maximum economics of purchase. In addition it increases identification of the part by purely its number. The most widely used system and that implemented by the RAOC and most companies is the Federal Supply Classification (FSC). "The structure of the FSC as presently established, consists of 76 groups which are subdivided into 595 classes. Each class covers a relative homogeneous area of commodities, in respect of their physical or performance characteristics, or in the respect that items included therein are such as are usually requisitioned or issued together, or constitute a related group for supply management purposes". Reference Federal Supply Classification 73. Whilst the numbering systems used for identifying groups have their uses most inventory control systems take classification one or more stages further. The disparity of price, use, profit potential or need (Public Sector), simple or complex and other factors depending on the product may be used to further classify inventory. It is not the method of classification or the steps in classification that are important. Classification is a time consuming, human intensive operation for even the smallest inventory. The classification must pay back the effort involved by producing some financial or quantifiable improvement to make it worth doing.

The RAOC Inventory and Companies A, B and C have all classified their inventory into 3 main classifications which may be subdivided further. These classifications are:

Class	Mil Definition	Civ Definition
INV CLASS 1	Those items which require detailed planning for procurement and/or repair, deployment and disposal.	Rotable/Equipments Those components of key importance to serviceability which are individually serialised to enable their origin to be traced. Maintained by repair or overhaul.
INV CLASS II	Items maintained by procurement and or repair depending on circumstances	Consumable /repairable
IV CLASS III	Items maintained by procurement.	consumable/non repairable

Civilian Military Classes

Figure 4-2

Academics and certain progressive companies, Company D is one example, have taken classification far beyond this temporary and unrealistic area. If the classification is not directly related to the Total Distribution equation and the Operational Policy of the company then it is argued that the classification fails to fulfil one of its main purposes. This benefit forms the basis of D Ray and S Millman's 78, case for optimal inventories. They argue that "stocks should not be dealt with in a blanket fashion; certain selling items are a lot more important than others." Whilst arguing that service levels are dictated by competition and what we can afford they identified, criticality, substitution, stock dispersion (multiple inventory levels), state of the market (increase/decrease) and distribution channels as possible variables.

Critical, vital and essential or whatever derivative is being used to define items of the highest importance represents the major stumbling block for the Inventory Manager. When viewed from the perspective of the customer any item that he fails to receive may be of critical importance to him. In the commercial context failure to supply has been investigated, studied, analysed and quantified but 'there is no theoretically correct answer' E Landau (1979). It is the area of degrees of importance however that some theoretical and practical work has had some bearing on Inventory control. J D Patton 1984 argues that there should be four essentiality codes for service parts. Failure to supply results in:

Code 1. Safety or Legality infringements.

Code 2. Equipment not operational.

Code 3. Degraded operation of Equipment.

Code 4. Minor cosmetic effect.

He does by inference however suggest that the number of equipments deployed by each customer should also be taken into consideration prior to holding the service part. His statement "a particular piece of equipment may be essential to a specific customer" destroys the clear grading of 4 types of stock. If a customer can regard a code 3 item as a code 1 item related to the equipments he possesses then the code is invalid as an inventory control tool. Within the context of customer expectations the military are similar to commerce. E W Smykay 1973 also attempted to produce a set of essentiality codes which differ significantly from J D Pattons. He suggested a set of combined values as follows:

Code 1. Must be immediately available to maintain operation of machine.

Code 2. Critical to continued operation that may be delayed not more than 7 days.

Code 3. Not critical to continued operation that may be delayed more than 7 days.

Although the military customers may all be Army they have individual equipments and importance within the overall structure. That is not to say that Armies have not studied essentiality but that no acceptable coding has yet been produced or implemented. The American Army in 1982 were unable to provide essentiality codes for research into Alternative Forecasting Systems carried out by Assistant Professor Dr J Wayne Patterson (82). Essentiality remains the undefined goal of inventory systems and the American Army have built into their computer systems the ability to rapidly implement some code or grading once derived. "Although essentiality rules for specific items within a heterogenous group of items have not been established, an essentiality function is included in the TVC equation for use when essentiality of some items in a group over other items is readily apparent and for use in the future, should such rules be established" DOD 4140.39 1985. M J Ploos Van Amstel approached the problem from a different angle. His views which are incorporated already in some private companies but none of those in the study concentrate on value and volume. He suggests there should be four main categories:

A Low Value Large Volume

B High Value reasonably Large Volume.

C High Value Small Volume

D Low Value Low Volume

Not content with these four categorisations he suggests that there are two other areas which can influence the categorisation and control of stock. The first, product characteristics, he argues is significant to all aspect of Physical Distribution and all of the Study Companies were aware of these factors. Within this area he suggests items may by their characteristics be moved from one category to another dependent on the ratio between volume and weight, products per standard carton, cartons per standard shipment and the sales (outlets) organisations which can sell (handle) the product. The second area, transportation, he suggests is "Not considered under inventory control". Within this area he has identified types of deliveries, distance, size of flow, speed of transport and the location of factory (depot) to sales (outlet) organisation. He concludes by stating that "different products have different requirements". If this is there-

SUMMARY OF CLASSIFICATIONS

Criticality

	Code 1	Code 2	Code 3	Code 4
J D PATTON	Safety or Legality Infrugement	Equipment not Operational	Degraded Operation of Equipment	Minor Cosmetic Effect
E W SMYKAY	Immediately available to maintain operation of machine	Critical to continued operation that may be delayed not more than 7 days.	-	Not critical to continued operation that may be delayed more than 7 days.

Volume classification

M J PLOOS Van AMSHEL	Low Value Large Volume	High Value reasonably Large Volume	High Value Small Volume	Low Value Low Volume.

Figure 4-2-a

fore correct then different products require different control techniques. It is questionable therefore whether categorisation should be based on value or volume or whether each individual item should be assessed on its individual characteristics. To operate an inventory control process which catered for each and every individual item within an inventory is, even with todays technology, some way off into the future.

Whilst all inventories have been classified in one way or another the only categorisations that have been implemented are based on Value, Repair or Volume. Every Inventory professional and their customers accept that this is insufficient but no essentiality or criticality categorisation has been found.

4.3. Forecasting Models

There are three methods of forecasting stock holdings. Each has been well documented varied and tried. No one system has been found which is all things to all stock. Proponents of each system compare and contrast its merits against either one or both alternative systems and by taking a small carefully chosen sample of inventories extol the virtues of the system they are describing. The three systems can be described as:

1. The statistical and mathematical manipulation of past data.
2. The explosion of equipments to produce master parts lists.
3. Strategy buying.

The average company inventory will respond to any of these three systems and there will be advantages and disadvantages dependent upon the method of implementation and the data capture prior to execution. Every inventory contains some new, some old and some mid life item headings so no matter how carefully implementation takes place there should be three degrees of accuracy or inaccuracy during the initial stages. The public and private companies used for evaluation are however atypical. Their inventories are not measured in tens of thousands but hundreds of thousands and their range of category of stock encompass that normally held by several companies. On one interview the remark was made that you could drop the Unipart inventory into the RAOC inventory and never see it again!

4.3.1 Statistical and Mathematical Manipulation

A mathematical model is dependent for its accuracy on the status quo being maintained. Most models whether purely mathematical or mathematical and statistical, start with the assumption that future demand is known and will mirror past demand. The classic sawtooth shown at Fig 4.3 is however representative of few types of inventory item headings.

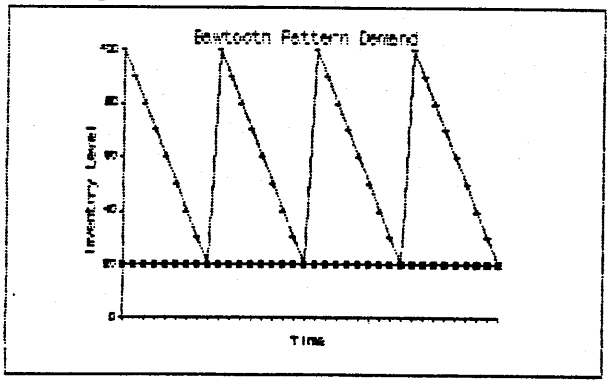


Figure 4.3

When such a situation is identified stock levels can be reduced to the minimum with little probability of stock outs occurring. A computer controlled inventory operating a derivative of this system is incapable of recognizing the difference between a perfect sawtooth and a

non-moving item. To a forecasting model constant regular usage is identical to zero usage. That is to say that as long as the standard deviation does not change then most computer forecasting models do not trigger alternative policies. Constant zero usage represents the finest most stable form of demand. This is however not acceptable to the provisioner, who regards zero usage as non credible usage history and maintains in many cases artificial stock levels just in case! Irregularity is a recognised problem and the more reactive model with some form of exponential smoothing allied with tracking limits is normally found. This amended model will normally cater for increasing or decreasing demands albeit with some delay. Dependent upon the weighting the forecast will track present or averaged past data. When used as a blanket model recognition of which phase of life the item heading is in is not possible. Once again the non-moving item will respond as the perfect part number. The major exception to the use of this model is however seasonality.

Fig 4-4 illustrates the likely tracking response of a complex model through the expected life of a spare and Fig 4-5 is a representation of a regular mid life item with a biannual seasonal surge.

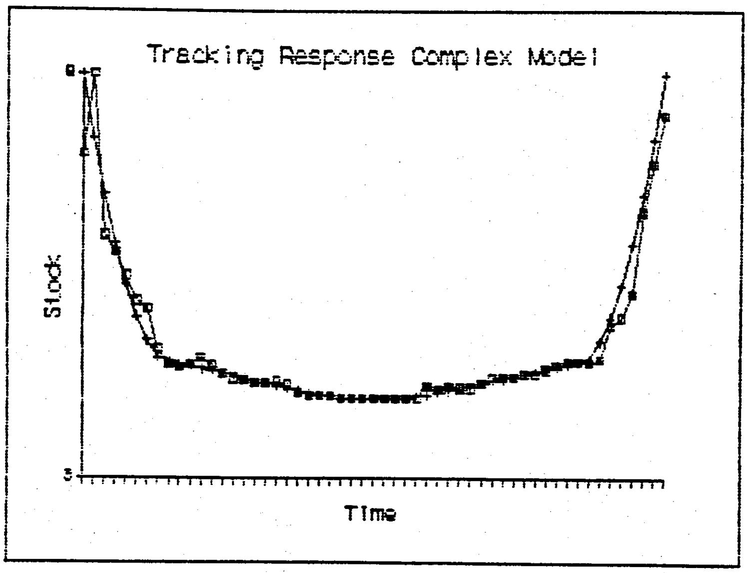


Figure 4 - 4

Initial disparity is directly related to initial estimation of mean time between failure. Complex tracking model tends to achieve greater availability of stock during the early life of an equipment.

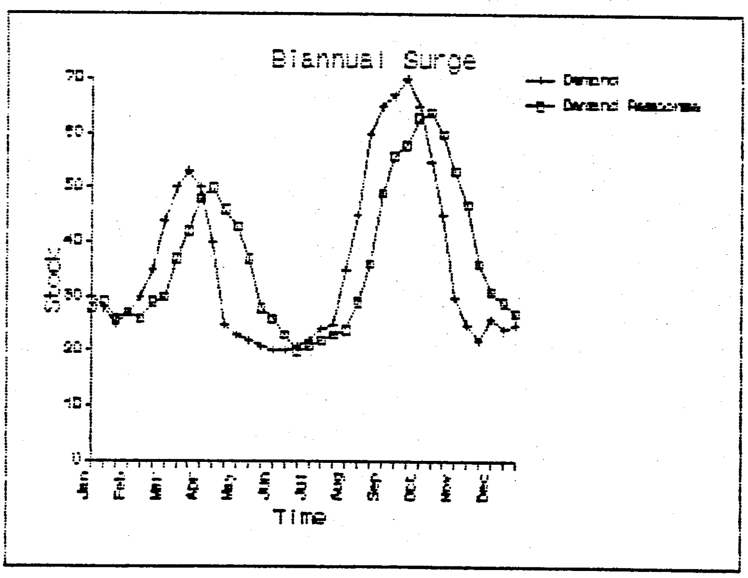


Figure 4 - 5

The major effort in manipulative mathmatical models has been to produce a reactive and sensitive formula which, using the minimum data, responds most closely with the actual demand with the least error. Research has concentrated on the more normal items and known factors affecting demand. Available models therefore can cope with standard distribution, Poisson distribution, forms of skewing, variable lead time, seasonal variation and variable demand patterns. Whilst the definition of variables is indicative of change it should be noted that the majority of the variation catered for by existing models is time predictable (eg seasonal) or represents minor (often insignificant) variation. Those more reactive and complex models have been designed largely to eradicate the number of manhours required to control inventory by allowing computers to control part numbers. This can however be a negative approach and this view is supported by E S Buffa 1983" The best results are seldom obtained through the mechanical application of a model. Subjective inputs from knowledgeable people can improve forecast accuracy".

It is accepted that different variables affect different item headings and inventories. The number of alternative models now available make the inventory managers task more complex. If he identifies that his system is not as efficient as he or his masters would prefer, what options are open to him? Does he opt for a new alternative model or a series of models to cater for each part of his inventory. J Sussams 1986 identifies the major benefit of choosing the correct method. "It is clear that a forecasting procedure which takes into account trends and seasonal patterns and which identifies and ignores exceptional, one-off demands, will generate fewer and smaller errors than a crude procedure which, for example simply takes this months demand as a predictor of next months demand. The more reliable the procedure the less buffer stock it is necessary to hold for a given cover". The majority of the proponents of models and systems however place a serious caveat on the models they wish the inventory manager to adopt. The RAOC system starts with the caveat that all demands are expected to fit the normal distribution curve, which with the size of the inventory is a somewhat absurd statement. The stand -ard deviation of demand within the lead time is a suitable measure of variability for all normal items. The inventories with which this thesis is concerned are however not normal. "There are certain types of business such as fashion goods, consumer durable and spare parts, where a large proportion of goods do not behave in the 'normal' manner". J Sussams. There would appear therefore to exist an ideal (academic) and a real (practical) situation with regard to forecasting. In the ideal world the conditions are:

a. Knowledgeable people control inventory.

b. Variables are known and predictable.

c. Models are good and adaptable.

d. The inventory is 'normal'.

In the real world however the more likely conditions in which forecasting models must operate would probably be:

a. Poorly trained and less knowledgeable people.

b. Variables tend to be unpredictable.

c. Models are partly successful and not adaptable.

d. The inventory is not normal.

The real world can best be summed up by the following statement made by T J Drakeford of LUCAS Electrical Limited at the 1987 ILPDM Conference. "Sometimes I feel more like a museum curator than a stock manager".

The existing models which are available today and brief comments on their applicability are shown in Figure 4.6.

Forecasting Models			
Serial	Model	Caveat	Comment
(a)	(b)	(c)	(d)
1	Simple Arithmetic Mean	Constant demand. Requires buffer stock in all cases to cater for variation.	Short range projective Does not attempt to cater for any known variable. Applicable when no deviation in demand pattern.
2	Moving averages	Demand should have standard deviation Requires buffer stock in all cases. Requires historical data.	Short range projective. Places greater emphasis on most recent data. Tracks seasonal and cyclic demand retrospectively.

Forecasting Models			
Serial	Model	Caveat	Comment
(a)	(b)	(c)	(d)
3	Exponential Moving Average	Variables should be constant and recurring. Requires buffer stock which is dependant on Lead Time.	Short range predictive. Will track, depending on weighting of constant. Will lead to serious over-stocking if Lead Time is excessive and variables are non-recurring. Does not forecast trend. Normally lags demand.
4	Exponential Moving Average (Trend Model)	As above	Model becomes more adaptive to real trend and smooths out random variation. Cannot immediately differentiate between random fluctuation and change in trend. Tends to increase Stock Levels but improves Service Level. Normally lags demand.
5	Exponential. Moving Average (Seasonal Model)	Requires 2 years data. Demand variability by month must be constant.	Does not cater for trend. Choice of smoothing constant affects forecast error. Product life cycle not catered for. Normally lags demand.

Forecasting Models			
Serial	Model	Caveat	Comment
(a)	(b)	(c)	(d)
6	Exponential Moving Average (Trend & Seasonal Model)	Requires 2 years data. Trend must be gradual and demand variability by month must be constant.	Choice of smoothing factors can seriously affect forecast. Increases computing time required. Depends on variables reacting smoothly. Can increase stock levels significantly when random demands occur, especially if the system is programmed with automatic buy sequence.
7	Exponential Moving Average Adaptive	Inventory must consist of medium to fast moving item headings.	Adaptive smoothing constant automatically implemented by computer eg Trigg Leach model 1967. Reduces manual intervention. Tracks more closely the changes in demand. Susceptible to random and seasonal variation No significant proof that there is any improvement over single exponential smoothing system.
8	Fourier Series Least squares	Depends on demand remaining constant by periodic month.	Increases significantly computer costs. Improves the fit to historical data. Tends to reduce MAD. Depends on the minimum random demands and normal item.

Figure 4.6.

4.3.2. Material Requirements Planning

If EOQ and ROL systems may still be considered state of the art, in that they are not totally or widely used then Materiel Requirements Planning (MRP) or Distribution Requirement Planning (DRP) must be regarded as innovative high technology. The explosion of an equipment into its Bill of Materials has been regarded as a preserve of those industrial concerns who concentrate their efforts on production.

However even within these specialised spheres the actual uses of MRP have been extremely limited, when considering that MRP was discussed and introduced in the 50's and 60's. MRP can be likened to a spider in that the data that it requires to function correctly must be woven like a web through the business to which it is being applied. This data must be accurate up to date and as pointed out by Orlicky 1975 its implementation depends for its success on the acceptance by everyone in the firm from top management to the MRP user on the workshop floor. SA MELWYCK and CJ Piper 1982 would further argue that MRP requires reasonable estimates of manufacturing lead times. The resurgence in interest in this particularly complex method of inventory planning can be attributed to the increasing availability and decreasing cost of high powered large memory computers. The ability to search several bills of materials for a particular part number with computer back up has produced the feasibility of the introducion of MRP at a much lower level than hitherto. MRP is however only usable in situations where the demand placed upon those items within the inventory is dependent based. It would be illogical to attempt to put an MRP based system into effect where only independent demand is received. Even where the total inventory held by a manufacturing company was known to be dependent based the implementation of MRP based systems has not always been successful. The failure rate for implementation has been extremely high and is quoted by MELWYCK and Piper 1982 as being in the region of 80-90%.

The concepts of dependent and independent demand are normally viewed in isolation and as their users are engineers or statisticians this is quite understandable. Implementation of new systems is expensive and normally results in dynamic change. Change in any area of life is viewed initially with suspicion. The present inventory control options discussed within firms is either to adopt EOQ or MRP in total. It is easier to affect total change than it is to do partial change. Total change with new systems and operating policies will invariably be more efficient than the previous inventory control system. Few companies have changed systems and the study companies who are working towards change do not intend to compare new versus old systems but service to customer improvements. Whether the service to customers is because of the new system or the changes in procedures of inventory control will be hard to analyse. It is debatable whether the same level of success could have been achieved purely by changing the procedures.

4.3.3. Strategy Buying.

Strategy buying covers those forecasting methods which lie between reliance on purely historical data and those which are dependent on a known or expected future commitment. It covers the pseudo scientific methodology of causal modelling and methodologies developed from the gut reaction of the provisioner. In its purest form it is an amalgamation of the two. Within inventory forecasting causal modelling receives scant attention probably because the variables are so difficult to define initially and their success even more difficult to quantity. It has and is successfully employed within the retailing sphere of inventory where customers are free. It is less accepted in a service environment where the customer is captive. Its greatest success is in those areas where there is a priori variable on which throughput can be based.

In the 'gut reaction' area of forecasting some outstanding results have been achieved. The final model however tends to relate only to that firm and products area where the methodology was developed. These systems are therefore very often in house and have few if any turn key applications. One of these, used under practical conditions and publicised is Focus forecasting. Developed by BT Smith of the American Hardware Supply Company and consisting of the input from each of the managers of discrete product groups 'gut reaction'. Smith produced these individuals concepts of forecasting their products into a suite of forecasting options. As each product came under review a forecast using each method in the suite was calculated. That method producing the most accurate prediction of the current periods offtake was used to produce the forecast for the next 2 periods. By this process the method of forecasting was automatically changed by the computer system to that which produced the most accurate forecast. The accuracy claimed for the system is a less than 2% variance betwen actual sales $ "throughput and predicted sales $ throughput.

4.3.4. Comparison of Forecasting Techniques/Methods

The table below represents the views of those authors listed at Annex A to 4.3.4 and the companies who participated in the research both formally and informally. The biblography at Annex A is placed here for ease of reference.

Techniques Models / Comparison Factors	Mathematical Modelling	MRP/DRP	JIT/KAWBAN	Strategy Buying
Cost	Low	High	High (1)	Low
Accuracy	Low	High	Low	High (2)
RISK Stock Out	Medium	High (3)	High (3)	Low (4)
Unnecessary stock	High	Low	Low	Medium
Wrong Location	High	Low	Low	Not known
Economic Risk	High	Low	Low	Not known
ACCURACY Dependent Demand	Medium	High	High	High
Independent Demand	Medium	Low	Low	Low
Seasonal Demand	Medium	High	High	High
Lead Time critical	No (5)	Yes	Yes	No
Safety Stock held	Yes	No (6)	No (6)	Yes
Reactive	Yes	No (7)	No (7)	Yes
Implementation	Simple	Difficult	Difficult	Difficult
Discipline	No	Yes	Yes	Yes
Customer	Free/Captive	Captive	Captive	Free/Captive
Application (8)	Any	Manufacturing	Manufacturing	Any
Reliance	None	Schedule	Offtake	None
MANAGEMENT Acceptance	None	Total	Total	None
Intervention	Intermittent	Regular	Regular	Intermittent
Computer Needs	Simple	Complex	Simple	Complex
Stockturn	Medium	High	High	Medium
Inventory depth	High	Low	Low	Medium

Table 4-1

NOTES:

1. High management input on set up and for every new product. This cost reduces rapidly if system efficiency is correct.

2. This methodology is normally only employed in inventories where the product throughput is high and relatively speaking regular.

3. Stock out is dependent on the accuracy of the schedule. MRP and DRP in their correct form attract no safety stocks. An error in scheduling therefore becomes critical quickly.

4. Strategy buying is normally used in an environment where the customer is free. Service level failures are not therefore as evident as those in a captive environment.

5. Whilst lead time is still very important safety stock will often allow considerable flexibility.

6. Safety stock should not normally be held. One of the successes of the system in real life is however that safety stock is held just in case or just because!

7. This relates to short term unexpected, unforecast demand or activity. Whilst schedules for MRP DRP can be revised this is normally at considerable effort.

8. Relates to the activity where the system is normally employed.

ANNEX A TO
PARAGRAPH 4.3.4

BIBLIOGRAPHY FOR FORECASTING TECHNIQUES AND METHODS

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CHAPTER 4B COMPANY SYSTEMS

4.4 Comparison of Systems

All of the companies investigated held the three categories of stock described in paragraph 4.2. All of the companies had systems whch dealt with complete equipments as special cases requiring direct managerial intervention. This to them seemed an obvious and wise step as these equipments represented a high proportion of their capital outlay on spares. The balance of the inventory in all cases was forecast on demand data with the possibility of some management intervention. Such diverse items as a hammer, a lifejacket, a resistor or a tin of paint were all dealt with by a forecasting model which was driven by historical demand data. Some of the companies and in particular the RAOC have attempted to subdivide this demand data into what should and should not be used for forecasting. All stock holding units less those that have a direct interface with customers will experience 3 types of demand:

a. Recurring.

b. Non-recurring.

c. Stock replenishment.

It is widely accepted that if it were possible to identify non-recurring demands then forecasts would be more accurate. If the level of non-recurring demands per annum are however constant it is a waste of managerial time to identify them. Initial identification must however come from the customer who according to the survey is not concerned with inventory control only with results. Non recurring demands must still be met from stock, failure to provision for them invariably leads to stock out. The worst form of non-recurring demand is the introduction of a better part or modification. No customer wants old stock when a new model or type is available. Policy however normally dictates that some customers will continue using old stock.

Any shortage of the new item will force customers to redemand on the old part number. The question faced by the inventory control system is what is a recurring demand and what is non-recurring. It is not yet possible to build a computer system to analyse each individual demand and make a subjective decision. The customer, within public concerns, directs the inventory. The customer must be forced therefore to attend some form of educational training session or the inventory control system must be redesigned. The customer however is often blamed for overstocking and over demanding when in fact it is the system which is at fault. One of the companies who took part in the study carried out a rebuild programme on equipments they had bought in second hand. All of the stock used on the rebuild was added into the normal recurring demand data. The demand data was therefore artifically inflated and stock in excess of £5,000,000 was unnecessarily procured.

The accuracy of historical demand data forecasting increases in proportion to the frequency of demand and the quantity demanded. If all inventories conform to a Pareto analysis (all of those in the study did when the complete high cost equipments were removed) then the probability of success using a forecasting system based on demand data only holds good for 20 percent of all the inventory. In addition this is only true if those 20 percent have a regular demand pattern evenly distributed throughout the year. All of the companies involved in the study had peaks of demand at various times of the year depending on their operational role. The items for which there were peak demands formed a high percentage of their top 20 percent. Whilst historical demand forecasting will cater for most periods during a year it will not cater for peaks. Two companies are actively pursuing a non demand based system for their complete inventory. From the data supplied by the study companies demand data systems are effective for between 5% and 15% of the total inventory. It is therefore argued that any company which relies on a single forecasting system for its complete inventory will increase the probability of both over and under stocking.

All of the companies held the view that their inventory was there to serve the customer and this was the main area of attention for the evaluation of the success of their inventory system. Only one of the companies carried out any tests on the accuracy of their forecasting models and none of the companies carried out any formal method of identifying over stocking. Most management effort was concentrated on the high value moving and low value fast moving items which by default run the highest risk of stockout. It can be argued that the control of the inventory was more crisis/reactive than proactive.

The main comparative areas are summarised in Figure 4-6 but specific salient points from each company are listed below with additional notes.

Company A	Notes
1. Concentrates its management and computer effort on 3% of its inventory.	
2. Customers participate in forecasting their requirements for next 2 years. Regular quarterly provisioning conferences with major customers.	
3. Each provisioner is responsible for a given number of item headings and his performance is evaluated.	Boots PLC also operate this system. Provisioners respond as they are in competition.
4. Trends are related to the number of eqpts deployed.	

Company B	
1. Present stock control accuracy is assessed as between 55/60%.	credibility of computer control brought into doubt.
2. The Company is vigorously pursuing an essentiality grouping	No progress to date.
3. Penalty of stock out is disproportionate to holding unnecessary stock.	
4. A Long Lead time is any time greater than 7 days.	

Company C

1. Attempted to use MRP but has now reverted to exponential smoothing.

2. Suffers from lead times in excess of 12 months on many items.

3. Is considering essentiality coding.

Bundeswehr

1. Believes essentiality holds the key to successful inventory control. Has made no progress.

2. Stockholding depth in excess of 10 years.

3. Has formalised Inventory Policy.

4. Believes Key to successful inventory forecasting is in responsive tracking.

5. Efficiency through:

   a. Training.

   b. Motivation.

   c. Educating customer.

6. Tactical Policy out of step with logistic policy.

7. Suffers random financial cuts.

US Army

1. Essentiality believed to be important and based on:

   a. Intensity of Management.

   b. Alternative sources of supply.

   c. Weapon system of grading.

   d. Cost of part versus equipment degradation.

e. Buy frequency and cost.

2. System still reactive not pro-active.

3. Size of inventory enormous in comparison to other companies.

4. Clear Policy Objectives.

5. Critical elements of supply defined:

a. Cost.

b. Management involvement.

c. Categorisation repairable/consumable.

Companies	NSNs	Value of Stock	Service Level	Policy Objectives	Control	Forecasting	Prime Depots	Regional Depots	Customers Holding Stock	Future Aims	Remarks
RAOC	740,000		95%		EOQ Manual & Computer	Exponential smoothing	3	5	12,000		
Company A	150,000	Over 100,000,000	90% within 90 days.	Customer Profit Decrease Inventory levels.	EOQ Manual Computer	Exponential smoothing					
Company B	700,00	315,000,000	98% (Objective)	Formally laid down 1986	EOQ Stock Control Accuracy 55-60%	Exponential smoothing to be complex MRP/Exp Matrix	1	65	130		
Company C	250,000	248,000,000	90%	No formal policy	EOQ	Exponential smoothing MRP discontinued	1	150			
Bundeswehr	450,000		80% 90% after 30 days elapsed	Maintain 90% of tactical eqpt at all times. Minimise the inventory. Maintain the stock production.	EOQ	Exponential smoothing				1. Move reactive. interactive tracking. 2. A manipulative EOQ system. 3. A Priority System.	
US ARMY	4,500,0000				EOQ	Exponential smoothing	CONUS 17	BAOR 2			

4.5. Company A

4.5.1. Company A is a major manufacturing company supplying complete assemblies and spares at component or sub assembly level. The main stores carry an inventory of approximately 150,000 item headings with a value in excess of £100 million. The stores support an internal manufacturing operation and repair facility and external customers. Between 60 and 70% of the company's spares turnover and therefore its main spares revenue earners lie in a very small percentage of the total item headings. At the outside this can be taken as no more than 3% of the total inventory. This element of the inventory by virtue of its high demand rate and profit potential receives the most management effort (see Note 1). The balance of the inventory (97%) is system controlled by a computer program.

4.5.2. The top 3% of the inventory is referred to as VSM (Volume Supply Monitored) and is further analysed/categorised into the top 1% (A) and the remaining 2% (A1). The A category is regarded as reasonably forecastable and the company base their forecasts on customer data feedback and regular customer provisioning conferences. Every item heading within VSM is assigned to a nominated controller whose performance to achieve a company agreed service level is monitored.

Note 1. Demand is essentially captive and non elastic, the problem (once the pricing policy has been determined) is to supply at least cost and with an acceptable level of customer performance. In the VSM range, inventory is held to an absolute minimum with the emphasis on 'pipeline management' on a part by part basis in the short term and individual attention to customer level forecasts which when aggregated produce a 1-2 year total forecast of requirement.

The next 2% is essentially manually controlled and included in this group are hard life items which are serially numbered. These items have a predictable life dependent on usage. Forecasting for these items is again largely dependent on customer feedback.

4.5.3. The remaining balance of the Inventory (97%) is subdivided into four major provision codes with each code having a separate form of provisioning logic. All are computer controlled but the capability of management/human control is retained. The provision codes are:

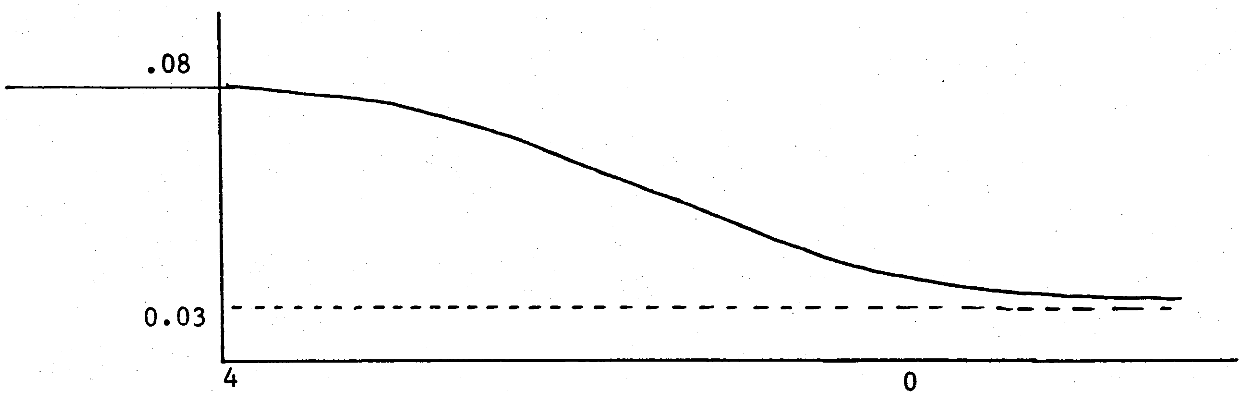
a. A. Relatively inexpensive short lead time items which are totally controlled by the system.

b. B. Semi-automatically controlled items. Schedule changes inside the Lead Time are manually vetted.

c. C. Any schedule change is recommended status only.

d. X. All items exhibit peculiarities which constrain their provision eg shelf life or new parts with no demand history or 'Lead Time business only parts'. Wherever possible they are not held but provisioned on a demand/order basis.

4.5.4 The company have been using a form of exponential smoothing on the A, B and C parts for the last decade. Whilst it is recognised as being inadequate the high variability of demand data precludes more sophisticated approaches. The company are still investigating alternative methods and have developed a "compound forecast" based on separate estimates of quantity and inter arrival time but this has as yet not been implemented. The present system uses the widely accepted sliding α constant. Where forecasts are greater than 4 per year α = .08 and the lowest α constant is .03.



Issues in 13 periods

Sliding α Constant Model

Figure 4-7

4.5.5 Trend forecasting is brought in at the family level and relates to the expected usage of the main equipments.

4.5.6. The company aim to achieve a service level overall of 90% from normal schedule within a 90 day period with residual shortages being handled by expediting. Buffer stock for fast moving items is based on LT error whereas for slow moving items a more complex function is used. The bottom line being that all items will be held regardless of movement. The image of the company depends on never saying they will not supply and their profit level is mainly geared on how quickly they can supply VSM items.

4.5.7. The objectives of the company holding inventory are threefold and all are given equal credence:

a. To provide a high level of service to their 250 customers and 8 satellite stores.

b. To generate a reasonable profit for the company whilst minimizing the cost of inventory and at an acceptable level of disruption of the supply process.

c. To decrease the total stocks in the supply process.

4.6. Company B

4.6.1. Company B is a major airline with a considerable fleet of aircraft and vehicles. The bulk of the company's inventory is controlled by the engineering division and this is in the region of 500,000 item headings with the total inventory being in excess of 700,000. The value of the engineering division's inventory is approximately £315 million. The inventory policy is to provide the right item in the right quantity at the right place in the most economical manner to a service level of 98%. The balance of 2% being provided by outside suppliers within the most acceptable time frame. The central inventory supports 65 engineering stores, colocated with the receipt and despatch store and 130 line station stores worldwide. In addition to planned maintenance the inventory is held to supply parts for non scheduled maintenance, overhaul and engine workshops and opportunity third party repair work. Line station stores hold on average 6-7,000 item headings but some of the more remote locations will only hold several hundred. A breakdown of the company organization is at Appendix 1.

4.6.2. The company have a single stock control system but each category of inventory engineering, MT, catering etc is held separately within the system. Although the engineering, MT and clothing inventories are separate the forecasting and stock control programmes implemented and used to date have been those designed by the engineering division. The inventory has been categorised into rotables, repairables and consumables in line with common aviation practice and this has been applied to all inventory. Forecasting has been based on planned schedule maintenance and historical data which has complemented a rather complex EOQ/ROL package. The complete system has been regarded as inefficient for some time and is undergoing a major review. The most serious problems encountered by the present system are:

a. The inaccuracy of data held on file.

b. The failure to forecast accurately.

c. The expenditure on expediting.

d. The fragmentation of the system and its inability to integrate with the relevant subsystems.

e. The reliance on human involvement.

A review of the system assessed the stock control accuracy as between 55 and 60 percent.

4.6.3. The proposed system will encompass all of the previous functions of the old systems. The aim of the system has been promulgated and is to reduce inventory levels and improve productivity by getting the right part to the right place at the right time at the lowest cost. Whilst there is nothing new in this as an objective it is worth noting that this aim has been formally laid down by the company. The company have however gone much further than this and identified why the old system failed and from this review worked out their actions to implement and maintain the new system. The concept that they have evolved is based on the fact that forecasting can only ever be possible if the input data is accurate. Inventory data has been subdivided into 2 elements, static and dynamic. Static relates to the identifying part number, compatibility and supercession whilst dynamic covers such areas as stock location, quantity, serviceability and status. The progression from this base through inventory recording, materials management, production control, costing, purchasing and forecasting all of which integrate at some level is strictly controlled by overt discipline, stock visibility at all levels and new inventory policies and workshop control mechanisms. The integrity of the data base hinges on a double check system which equates human input and bar code technology. The aim of the new system is a stock control accuracy of 98% or greater. This degree of accuracy has been achieved by a division of company A. At this level of accuracy the company could still expect up to 40,000 erroneous transactions per year.

4.6.4. The new forecasting system is still to be implemented but will be based on a matrix dependent upon the status of the part. Initial thoughts are that forecasting for planned maintenance will to some extent be based on a MRP system, hard life items on forecast flying hours whilst consumables will probably be forecast on historical data smoothed by some derivative formula based on a Poisson distribution. It is highly probable that the elements of inventory associated with

MT and clothing will follow one of these paths. The maintenance control programme will constantly monitor the Mean Time between failures and update the forecasting models regularly. One specific area of interest which the company may pursue in the future is the concept of essentiallity coding. No work has as yet been done in this field.

4.6.5. A pareto analysis of inventory by Throughput value and usage was carried out and is graphically represented at Appendix 2 and 3. The analysis was carried out from both quantitative usage and cost throughput. The results were not dissimilar from the analysis of RAOC inventory holdings. Whilst the company operate in a totally different area to that of the RAOC it can be deduced that the constraints on the system are such that the inventory is forced to carry far greater depth and breadth of stock than that expected from best commercial practice. The identifiable constraints that increase this stockholding are:

a. Failure of supply can have catastrophic financial effect.

b. Supply reaction during an emergency situation must be within the minimum possible time.

c. Spares holding cost and investment are a small proportion of the possible benefit/gain.

d. The quality of serviceability must be maintained above the acceptable standard set in most commercial concerns.

e. Resupply from outside agencies is often lengthy and in certain cases impossible.

Notwithstanding the above, competition is sufficient to warrant increased attention on reducing the size and scale of the inventory. This pressure has resulted in the current review and changes and is reflected in the present attitude being adopted within the RAOC and other companies researched.

APPENDIX 1

COMPANY B ORGANIZATION

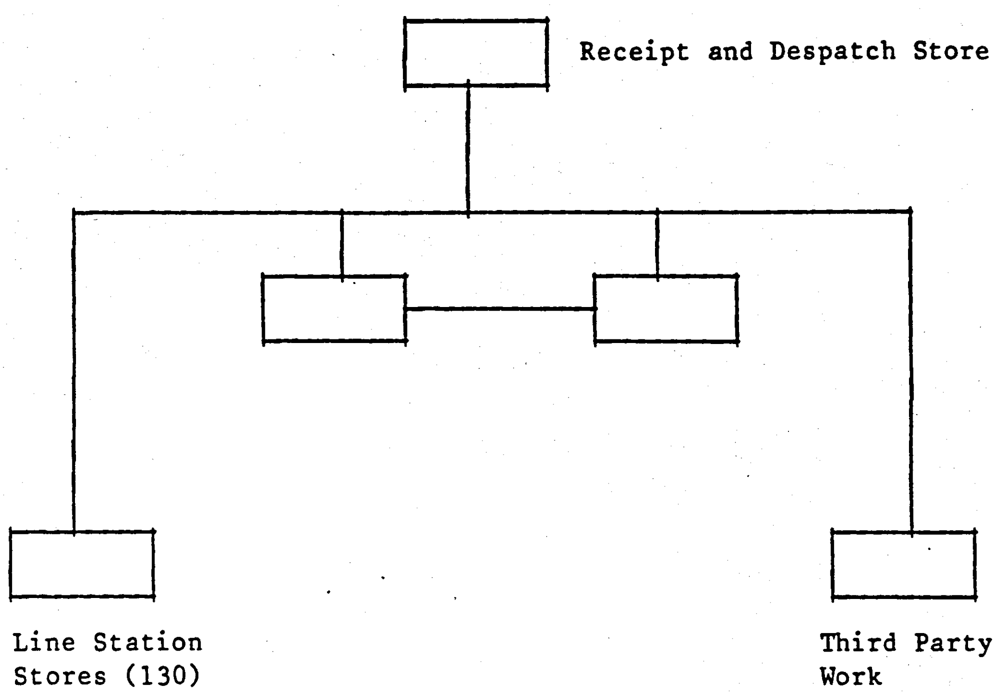


Figure 4-8

Receipt and Despatch Stores. Carries out the functions of Receipt and Despatch. All items that pass receipt inspection are passed to their parent engineering store.

Engineering Stores. Can act as primary depot for spares unique to its operational task and as a secondary depot for commonality items

Line Station. Acts as a tertiary depot holding fast moving or essential items only.

Note: The receipt/despatch store only receives engineering items. Other departments have their own receipt arrangements. There is no "Central" Store for the company.

PARENTO BY THROUGHPUT VALUE COMPANY B
ENGINEERING STOCK EXCLUDING ROTABLES

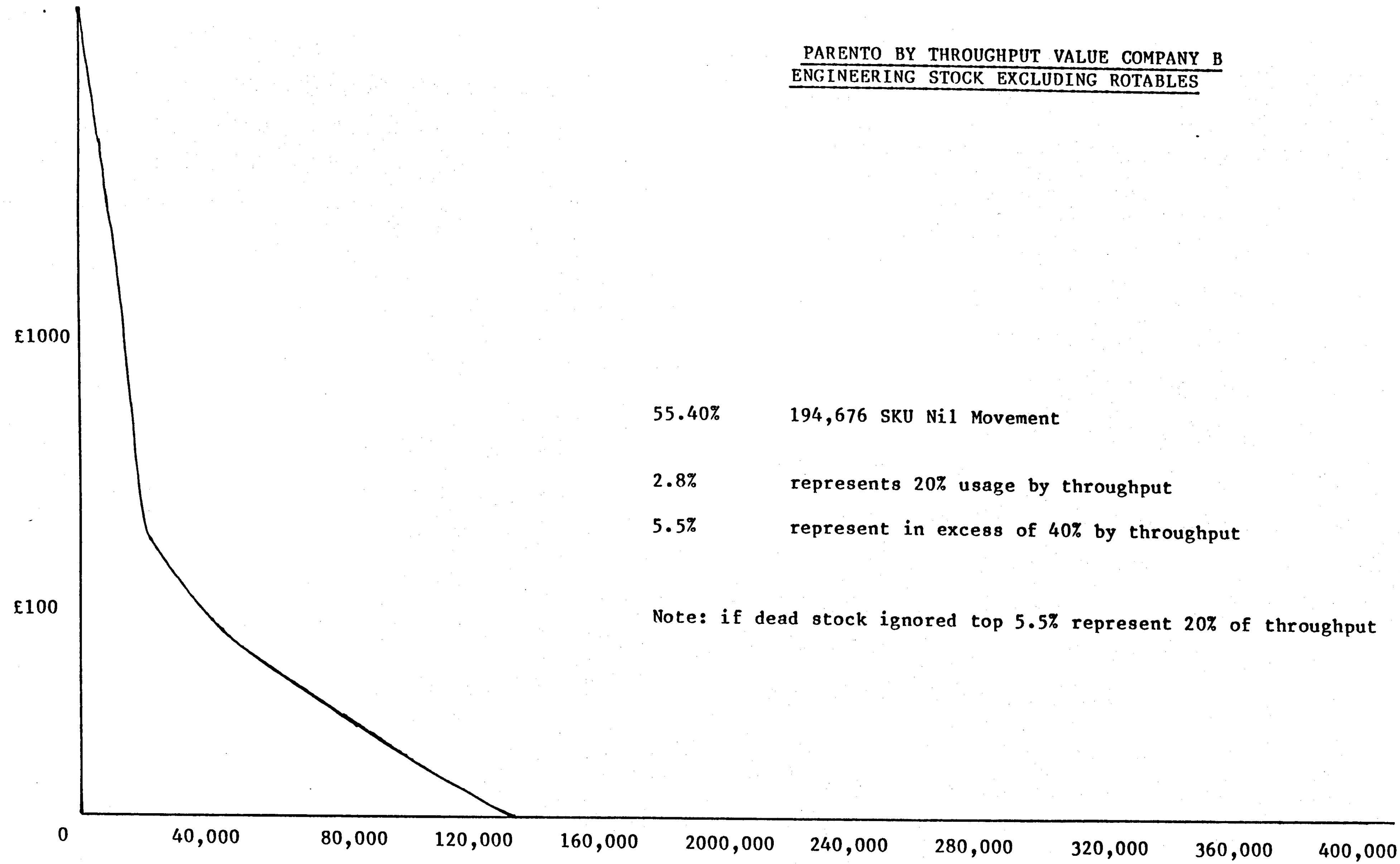


Figure 4-9

PARENTO BY USAGE COMPANY B
ENGINEERING STOCK EXCLUDING ROTABLES

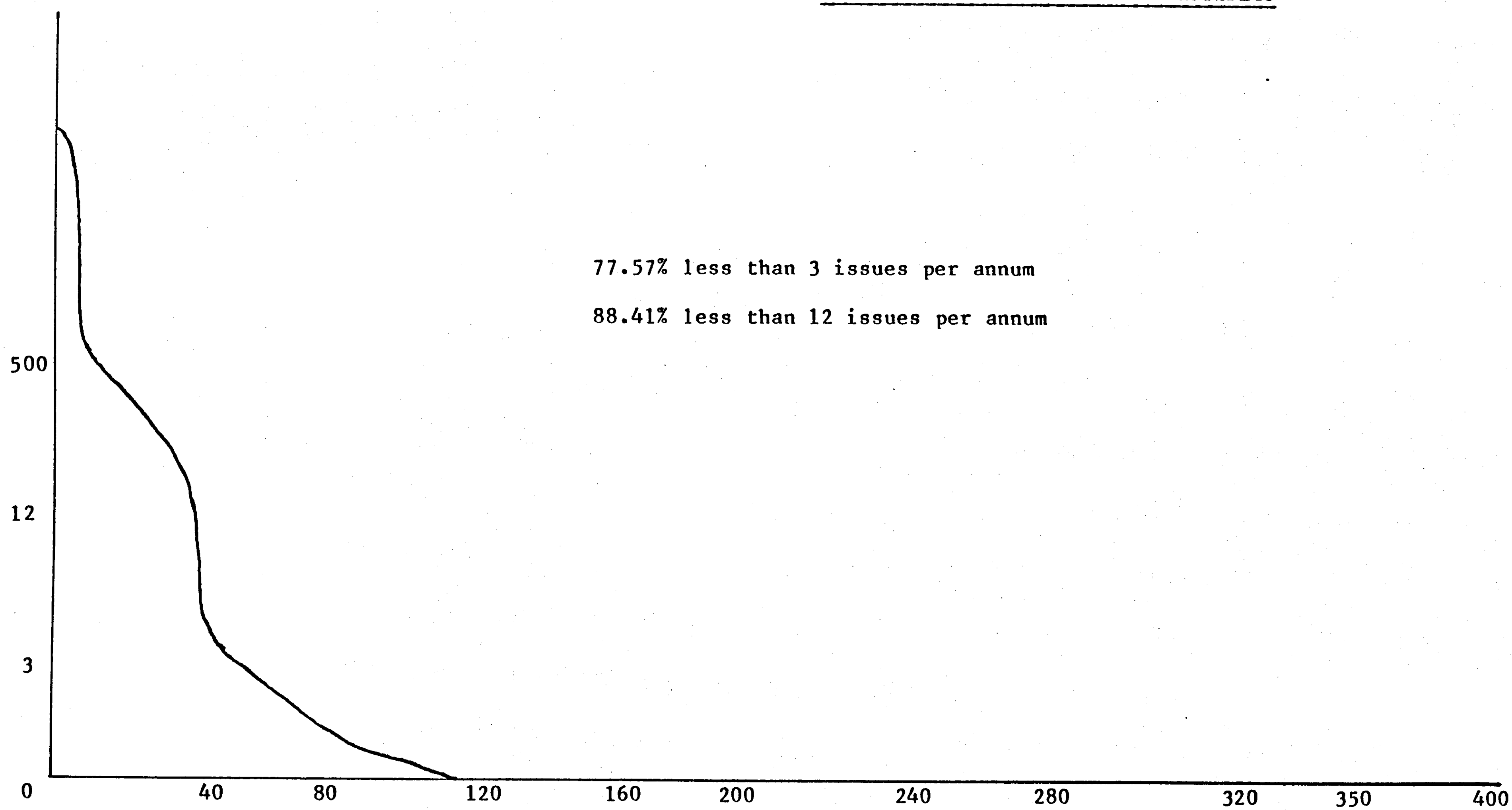


Figure 4-10

4.7. Company C

4.7.1. Company C is a major conglomerate involved with the production and extraction of raw materials. It has an annual turnover in excess of £4Bn of which expenditure on materials and equipment is about 700 million annually. This includes the purchase of new machines which are classed as capital items but of this 700 million approximately 46% is expended on spares. The Company's inventory consists of about 250.000 item headings which are classed as live but considerably more items are bought but not stocked or allocated part numbers. The complete inventory is held on one data base and forecasting is by straightforward exponential smoothing with the facility to input manual overrides. Stock control depends on the characteristics of the item. The average stock holding is in the region of £248M with an annual issues of approximately £582 million. The Company has about 150 operational locations all of which will hold inventory. The majority of spares, approximately 70% of the total stock, is held in central stores to support the main workshop facilities. The balance of 30% is divided between the operational locations and comprises in the main of the following:

a. Bulky low value items.

b. Items with regular high demand.

c. Items unique to that operational location.

d. Stand-by spares for vital equipment.

Expensive high demand items are generally controlled from Central Headquarters and the reserve stocks are held centrally within each major operational area because this facilitates liaison both with the suppliers and the operational centres.

4.7.2. Workshop overhauls of operational machines account for the major part of the usage of spares. These overhauls are planned in advance but numerous changes to the plan are necessary. Overhauls are often initiated following machine failure, which is of course unpredictable. Other overhauls occur when operational locations are closed temporarily or permanently, and again there is considerable uncertainty as to when this will occur or what type of machine will be due in for overhaul. Each machine has a bill of materials held as a computer record. A copy is given to the workshop inspector when the machine is stripped down and he records the materials necessary to complete the overhaul. This list or information for the particular job is then input to the computer. The computer consults its history and calculates the rates of usage of all parts of the bill of materials. These rates of usage may be overwritten by the workshop, for example if there is a modification to the machine, or if a trend is apparent in the failure rate of certain parts. The computer can combine its rates of usage with any notified change in the overhaul programme to alter the forecast annual demands for all of the machine parts. Such an exercise will be initiated by a stock control officer in the event of a significant difference between the 6 months forward programme of the workshop and the previous 6 months actual throughput. Whilst this operation may appear terribly simple it is in fact quite complex for even the computer system because many parts are used on several different machines and many are used at operational centres as well as workshops. The system is dependent upon the rigourous use of the listing documents being input from the workshops to the computer systems.

4.7.3. All stock items held by Company C are the subject of computer records in an enormous database which derives the automatic provisioning system. The Company have an aggressive forward-looking policy to inventory forecasting and stock control which is not immediately apparent by their use of ROL, ROQ systems. Until 1979 far more sophisticated procedures were in use, involving a calculation of demand variability. This was abandoned because it tended to thwart useful manual interventions by stock control officers. In principle, provisioning for workshop overhauls is a material's requirement planning problem. There are, however some serious difficulties associated with introducing MRP:

a. The workshops forward programme is often inaccurate.

b. There is a natural randomness about the rates of usage of parts.

c. Some lead times are extremely long.

d. Some parts are demanded by operational centres as well as workshops.

4.7.4. In addition, one of the prime advantages of MRP does not apply: the Company does not want to explode into multiple levels of sub assembly as a manufacturer might. There are only 2 levels, machine and part, although MRP might be some help in dealing with parts common to several machines. Another MRP feature with limited application is the feedback loop; there is no chance that areas demands can be altered to suit the provisioning process, although MRP might help the Company to produce convincing explanations where those demands have not been met.

4.7.5. The Company have therefore returned to a demand forecasting system of simple exponential smoothing which may be overwritten by manual intervention. Stock is reviewed frequently, and if the ROL exceeds the notional stock, the system:

a. Searches for an inter store transfer.

b. Consults internal rules to see whether an automatic order may be produced.

c. Produces an order suggestion for the attention of a stock control officer.

4.7.6. The Company is in a state of reorganisation and until such time as this reorganisation is complete no major changes within the inventory control and forecasting systems are expected. However one of the areas which has recently been looked at and a trial system is running, is a facility called the "kitting system". Currently the workshop lists are picked from central stores as soon as they are received. Unavailable parts are added later for those not in stock. Thus large sets of parts clutter up the workshop for some time before assembly can begin. The kitting system will allow parts to be supplied as complete kits when they are required, rather than as incomplete kits when they are ordered. Analyses have shown that this will reduce physical stocks without reducing the service level to the workshops, and considerably ease the administrative problem associated with this kind of provisioning. As a by-product, the computer will issue the storeman with a picking list to facilitate his work.

4.8. US ARMY

4.8.1. Overview.

The Department of Defence (DOD) logistics system encompasses the total logistics functions within the US Army. This includes the wholesale logistics system, retail logistics system (overseas), and Continental United States (CONUS) logistic system (wholesale and retail). Whilst the study is only concerned with inventory and its control it is necessary to understand the scale of operations and responsibilities of DOD. The deputy Chief of Staff for logistics (DCSLOG) has responsibility for physical distribution policy, tailored to fit the Army's mission. It is at this level where the separate distribution functions of supply and transport are co-located. The Director of Supply and Maintenance has staff control over the supply aspects of physical distribution whilst the Director of Transportation and Services co-ordinate movement with all service departments. The Army Material Command (AMC) has the primary responsibility for the wholesale physical distribution functions within the Army. AMC consists of a world-wide network of such military installations and activities as materiel readiness/commodity commands, depots, laboratories, arsenals, maintenance shops, proving grounds, test ranges and logistical assistance and procurement offices throughout the United States. The Commander of AMC has three deputies to assist in the accomplishment of the mission. The Deputy Commanding General for Material Readiness (DCG MR) is responsible for the receipt, storage, issue, and transportation of the inventory in the physical distribution system. The Depot

Systems Command (DESCOM) performs these functions under the guidance of the DCGMR. DESCOM consists of twelve depots and seven depot activities where the inventory is physically received, stored, maintained and distributed. There are seven Maintenance Depots which serve primarily as major maintenance facilities and perform (overhaul/rebuild) maintenance functions. They store, maintain and distribute specific high dollar Principal items, to the depot level. Two ammunition depots are responsible for the storage distribution and maintenance of special weapons. Three Area Orientated Depots (AOD) have the primary mission of the distribution of Secondary items to units located in a specific geographic area. Finally there are seven operable depots that have had their Missions, personnel strengths and overhead cost reduced to that of reserve storage status capable of greatly enlarged activity if needed. They are remote storage sites under command of a distant command depot. The present US Army depot system serves as the primary storage and distribution point for the Army wholesale system. When directed it also performs storage functions for DLA, GSA and other military services.

The Defence Logistics Agency (DLA) is an agency of the DOD headed by a military director responsible to the Secretary of Defence for providing supplies and services used in common by the military services. DLA is essentially the manager of the wholesale level responsible for the most commonly used items such as food, clothing, medical, textile, chemical, industrial, petroleum, construction, electronics and general supplies. The director has delegated responsibilities for physical distribution to the Executive Director for Supply Operations who deals directly with the Defence Supply Centres which perform the wholesale supply management functions.

Six DLA depots are charged with the receipt storage and issue of supplies as directed by the Defence Supply Centre's. Classified as principal distribution depots, they provide distribution to all activities within a designated geographical area. In addition DLA commodities, are handled by specified Naval depots.

General Services Administration (GSA) was established in 1949 to provide an economical and efficient system for the management, procurement and distribution of supplies used by all government agencies (currently 49,000 item headings). The GSA is not a part of the DOD but it does play an increasingly important role in the field of procurement and distribution of supplies and in the location and management of the national stockpile of critical and strategic materials.

Army Materiel Command (AMC) fulfils the basic mission of Army logistics in supporting the soldier in the field with what is needed, when, where and in the quantity required at a minimum expenditure of resources. The AMC performs research, development, procurement storage and distribution on virtually every item in the Army inventory. In addition the Army distribution systems provide many DLA and GSA items to units in the field.

A Direct Support System (DSS) is operated with the primary function of providing direct to the customer selected classes of supply as follows:

US ARMY CLASSES OF SUPPLY

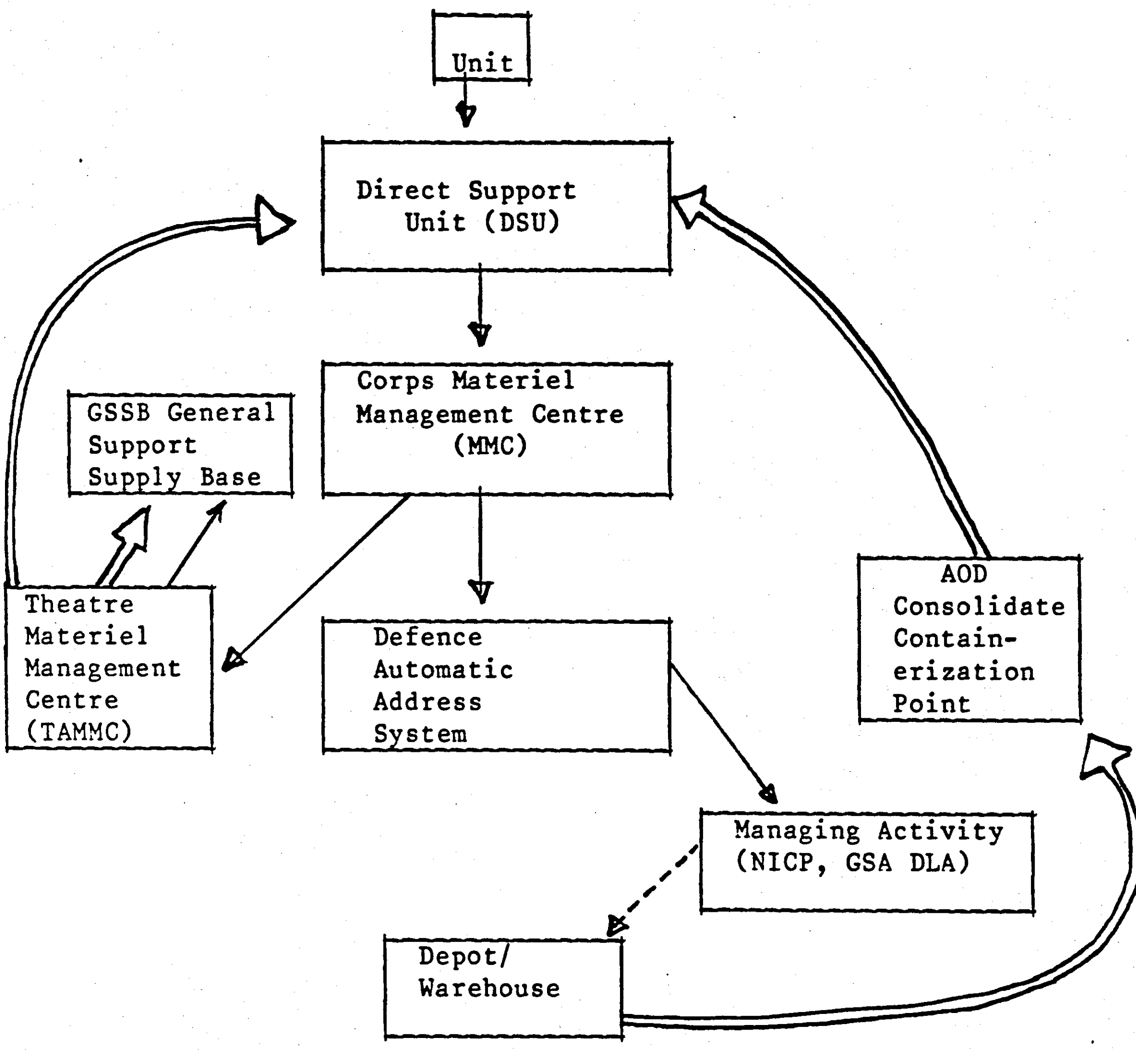
a.	Class I	-	Subsistence
b.	Class II	-	Clothing, tentage, administrative and housekeeping
c.	Class III	-	(Packaged) Petroleum, oils and lubricants.
d.	Class IV	-	Construction material.
e.	Class V	-	(Missile components only) Ammunition
f.	Class VII	-	Major end items.
g.	Class IX	-	Repair parts

Figure 4.11.

In DSS, supplies are moved straight from the CONUS wholesale supply base directly to the customer bypassing the overseas storage activity or CONUS installation Supply Divisions. The flow of information and material is shown at Fig 4.12.

The most important factor to remember when examining the US system is the sheer size in relation to UK, FRG or the study companies. The inventory consists of some 4.5 million item headings and this will become more relevant on analysis of the findings.

US ARMY FLOW OF INFORMATION AND MATERIEL



___________ requisition flow

\- - - - - - Materiel Release Order

=========== Materiel flow

FIGURE 4.12.

4.8.2. The Inventory

The inventory is subdivided into 2 classes wtih Class 2 being further subdivided.

Class 1. Principal end items, such as ships, aircraft, missiles, ammunition and vehicles.

Class 2. Secondary Items:

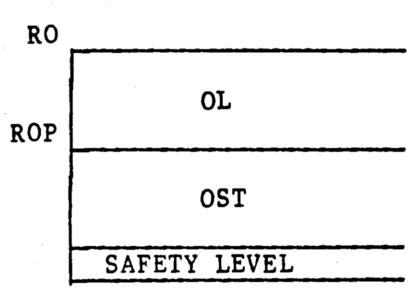
a. Reparable components, sub systems and assemblies eg truck transmissions, helicopter blade assemblies, missile guidance packages etc.

b. Consumable repair parts eg brackets, spark plugs, electron tubes, bolts etc.

c. Bulk items and material eg sheet aluminium, welding rods, gasket material, steel plate, textiles etc.

d. Expendable minor end items eg soap, bandages, canned beans, socks, canned oil etc.

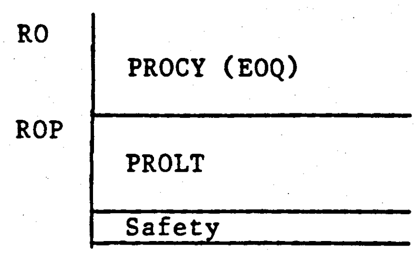
Inventory management in the United States refers to spare and repair parts (secondary items) and not to major items (Principal End Item) which are stocked only for specific purposes. Within the US Army, inventory management is divided into wholesale and retail systems. The retail levels are based on days of stock and build a Requisition Objective (RO) consisting of Operating Level (OL), Order and Ship Time (OST) and Safety Level (SL).



RETAIL LEVEL BLOCK

Figure 4.13.

The wholesale level of inventory management employs the requirements objective which (in simplified terms) is composed of the Procurement Lead Time (PROLT), Procurement Cycle (PROCY) and Safety Level(SL).



WHOLESALE LEVEL BLOCK

Figure 4.14.

The Requirements Objective is considered to be the maximum quantity of stock that properly should be at hand or on order. The procurement cycle dictates the frequency of purchase. This is an Economic Order Quantity computation which is then constrained. The present constraints dictate that EOQ(C) will be within the range 3 to 36 months with certain obvious exceptions eg shelf life. The present system however is operating with a concept known as annualized buy in which the minimum buy is 12 months worth of stock. This is an interim measure until EOQ formulas, that take quantity discount pricing factors into consideration, are developed.

Procurement lead time (PROCT) consists of Administrative Lead Time (ALT) and Production Lead Time (PLT). ALT begins at the time the requirement becomes known and continues until a significant quantity of stock is received (30 percent for the US Army). Cost to hold and Cost to order calculations are performed by the different managing activities and often for particular segments of the inventory. The total variable costing equation which forms part of the EOQ should be built up from the Cost Hold, Cost to Order and the implied cost of time weighted shortages. The shortage parameter may be determined in several ways but should relate to the essentiality or operational importance of the item. "Although essentiality rules for specific items within a heterogenous group of items have not been established an essentiality equation is included in the TVC equation" Reference to DOD Directive Systems Transmitted 4140.39 Ch 1 Dec 310985.

Whilst essentiality has not been agreed the manual identifies the parameters which may be of use when programming essentiality into future systems:

a. Intensity of Management.

b. Availability of Alternatives Sources of Supply.

c. Essentiality of weapons systems.

d. Essentiality of item.

e. Relative cost of part to weapons system that would be deadlined if part is not available.

f. Requisition frequency and dollar value of annual demands.

There would appear to be some serious double talk within this particular area of essentiality. Firstly it forms a integral and important part of the TVC equation. Secondly to utilise it you group the essential parts together. Regrettably it doesn't carry on to say what is essential and how to identify it. The variable cost to hold reflects the monetary penalty attached to keeping inventory in anticipation of future use. It is assumed that this cost is linear to the amount of on-hand inventory held and is thus expressed as the cost per year per dollar of average value of on-hand inventory. The variable cost to hold rate is established as follows:

Element	Value
Investment cost	10% per dollar per annum
Storage cost	1% per dollar per annum
Obsolescence cost	Variable
Other Losses (shrinkage)	Variable

Safety level is normally a Variable Safety Level (VSL) at the wholesale level and a Fixed safety level depending on the number of days stock held at the retail level. The VSL is a statistically derived formula based on the standard deviation of PROLT, demands and the desired level of protection using the Normal Statistical Distribution.

The cost to order an item of inventory to be used in the determination of annual variable cost to order cost (OC) will be dependent on the type of procurement method used in placing the requirement on order. These costs are applicable only to procurements made at Inventory control points for centrally procured items.

Three basic costs to order are developed to cover the following type of procurements:

A. For items likely to be procured using the small purchase techniques (contracts of $2,500 or less).

B. For purchases where a call-type contract is employed.

C. For purchases where the contract value is likely to be greater than $2,500 and where negotiated, advertised or other procurement methods are employed.

The costs to order should be updated as a minimum every two years.

The US inventory, similar to the RAOC inventory, is subdivided into two major categories which are then further subdivided. These categories relate to the characteristics of the item heading. Principal End items are normally complete equipments and are not provisioned by inventory calculations but Force ratios, Political policy, Deployment expectations and Tactical considerations. Release of these items is not by normal demand and issues are made only to maintain or increase DOD equipment tables. All other items which do not fall into this category are classed as Secondary items and these are generally managed by computer systems with varying degrees of human intervention. Repairables and consumables are found within this category. The DOD has deduced a grouping classification to increase the effectiveness of supply management decisions. DOD assessed the critical elements of supply as cost, management involvement and whether the item was repairable or consumable. The cost element depends not on the stock value but the issue rate and the following categories exist:

Very High	=	Greater than $500,000 per annum
High	=	Between $50,000 to $500,000 per annum
Medium	=	Between $5,000 to $50,000 per annum
Low	=	Between $0 to $5,000 per annum

It should be noted that low includes all items on which zero demands have been received. Low within public bodies taking part in the study always contains the highest percentage of inventory. To minimise movement between groupings items are allowed to experience a fluctuation of + or - 10% of the boundaries before they move between groups.

The second element of inventory control used in the grouping is the degree of management intensity. The US Army believe that the management intervention required will normally relate to the dollar value of predicted or actual demands. They feel however that the monetary inventory value (stock) or the criticality/essentiality of the item may also influence the level of management work required. DOD 4140.33 of June 12 1968 even went as far as to define both critical and essential:

Essential: A support item or a repair part whose lack renders the supported system or Principal End item inoperable.

Critical Item. An essential item which is in short supply or expected to be in short supply for an extended period.

Each degree of management intensity was expected to be influenced by the essentiality or criticality of an item. As discussed earlier the essential and critical definition has neither been accepted or implemented. The degrees of management are defined as:

Very High - Intensive reviews and analysis required. Day to day management input. Global Asset management. High speed transport for issues.

High - Normally reviewed every 3 months. Global Asset management and high speed transport may be required.

Medium - Review of no less than 6 monthly intervals. Normally at ROP. Asset information at wholesale level only.

Low - Minimum of one annual review. Normally at ROP. Asset information at wholesale level only.

Once this information has been compiled the following Supply Management Grouping Codes (SMGC) may be produced.

Designators

R = Repairable C = Consumables

V = Very High (Over $500,000)

H = High ($50,000 to $500,000)

M = Medium ($5,000 to $50,000)

L = Low ($0 to £5,000)

1 = Very High Management

2 = High Management

3 = Medium Management

4 = Low Management

MANAGEMENT PRIORITY MATRIX

Repairable SMGD	Repairable SMGC	Demand Value or Planned Issues	Degree of Management Intensity	Consumables SMGD	Consumables SMGC
RV1	A	Very High	Very High	CV1	M
RV2	B	Very High	High	CV2	N
RH1	C	High	Very High		
RH2	D	High	High	CH2	Q
RM1	E	Medium	Very High	CM1	R
RM2	F	Medium	High	CM2	S
RM3	G	Medium	Medium	CM3	T
RL1	H	Low	Very High	CL1	U
RL2	I	Low	High	CL2	V
RL3	J	Low	Medium	CL3	W
RL4	K	Low	Low	CL4	X

Figure 4.15.

There are eleven different groupings for repairables and consumables with a total of 22 groupings within the secondary item heading inventory.

4.8.3. Discussion

Whilst the grouping codes look sound they rely on historical data and are reactive not pro-active. They do not indicate to a supply manager where his attention and effort should be allocated until the problem has already happened. The key element missing from the system once again is the importance of the item heading to the operability and mission of the fighting forces. Issues during peace are no indication of the scale of issues required during tension or conflict. The definitions of management effort do not relate to logistical considerations but time and manpower costs.

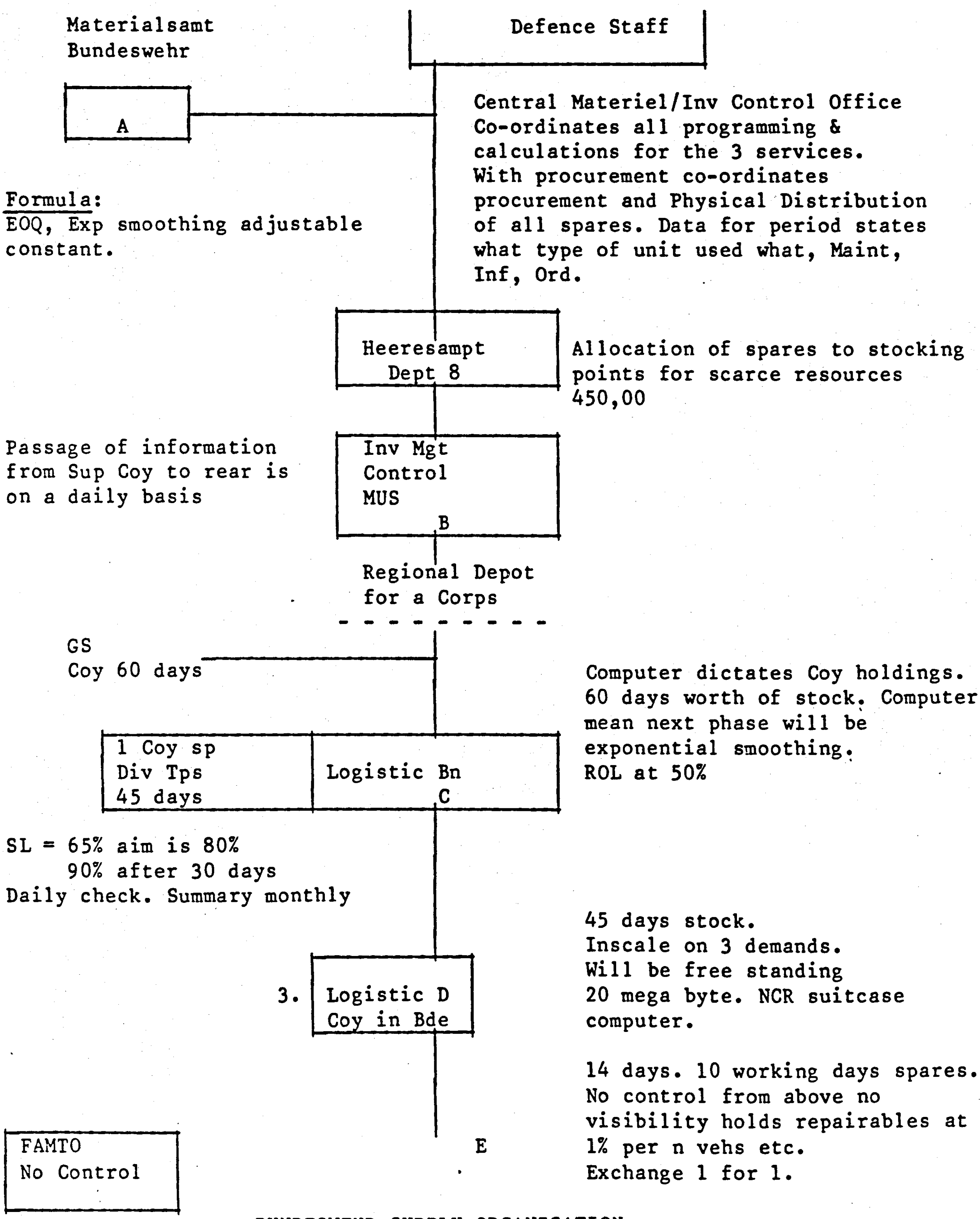
4.9. BUNDESWEHR

4.9.1. Introduction

It is relatively easy to dismiss further analysis into a subject area when the initial research appears conclusive and additional investigation is difficult and costly. Early in the study requests had been made to both the American Army and Bundeswehr to allow field studies to be carried out. Both had very quickly produced detailed procedural systems analysis papers which defined the forecasting and Inventory control systems in sufficient detail for a comparison to be made. Towards the end of the second year of the study continued pressure by the Military Liaison Officer (Lt Col T Glen) resulted in authority for a one week field trip to the Bundeswehr. Releasing money at short notice from any organisation is difficult and travel and accommodation budgets in public organisations are under constant scrutiny. Authority and finance was eventually granted from DGOS's personal budget (which gives an indication of the difficulties which had to be surmounted).

The study and hypothesis has largely been concentrated on 3 variables which have sub variables which have no fixed priority. These variables Inventory, Policy and Control were therefore used as the basis for the approach to the field trip. As there was a minor language problem a set of topics (Annex A) for discussion were forwarded in late October 86, translated and disseminated for discussion in January 1987. Structural bodies may look similar, whilst on paper, but the areas of their control and their (German word for power) are often totally different. The first element of each of the 3 visits was to ascertain where each level of the organisation fitted in to the system and where its actual power stretched to. The analysis was in all cases bottom up and top down with the intention of identifying crossovers, interfaces and voids.

The organisational diagram is at Figure 4.9.1 with supporting additional notes which may be read out of context.



BUNDESWEHR SUPPLY ORGANISATION

Figure 4.16.

4.9.2. MATERIALAMT DER BUNDESWEHR (MATAMT B)

The Matamt B is the central supply control office for the three services, Army, Airforce, Navy which constitute the Bundeswehr. Responsible to the Defence Staff for the efficient operation and control of all systems and budgets and comparable in some respect with the MOD but not with LE(A). Co-located with this unit is the Cataloguing authority for all three services. The charter of operations conducted at this level cover the control and monitoring of sub systems, central financial and purchasing control, and the identification and eventual implementation of future systems. It was the current options of the 'think tank' for future systems research and an explanation of present system policy which was the aim of the first visit of the field trip.

The Bundeswehr are actively searching for economies within their present supply system. The system in operation is antiquated and both manpower and financially expensive to run. Only levels A and B are currently computerised and the information and systems that were programmed are a duplicate of the manual system (see Chapter 2). The intention is that new computers and new programmes will be in place in levels A and C within the next two years. The software for these systems, the formulae and calculations are being written in house by German officers. The US Army Milstrip (with some variation) is the present manual system and as some Bundeswehr logisticians are trained and work with the Americans there is some similarity with the two systems. The forecasting and Inventory control systems rely on standard EOQ formula, exponential smoothing and fixed management constraints. The Bundeswehr have an efficient and smooth operating system but they are not content with it in its present state.

The improvements that are being researched do not differ from those goals of Private or Public inventories and are similar if not identical to those reviewed in Chapter 3. There is one difference between all of the Companies and Armies covered in the thesis and that is "There is currently no method of assessing what service level is achieved by the supply system". German Staff Officer Bundeswehr Matamt 13 Jan 87. Input of safety stock to guarantee supply is calculated at 90% for all items. The Germans are therefore in a rather special predicament in that they have no set level of achievement from which they can subsequently measure their improvement. The additional disadvantage however is that it is virtually impossible to judge the efficiency of the system using normally accepted PDM calculations and standards.

There are 3 main areas for the new operating system which are being worked on:

Area 1. More reactive/interactive tracking.

Area 2. A manipulative EOQ formula.

Area 3. A Priority System.

All three are in the theoretical stage but models of Areas 1 and 2 are being tested. Area 3 MATAMT B believe, holds the key to the eventual economic implementation of Areas 1 and 2. Area 3 is causing concern within many inventories not just the Bundeswehr. The concept of area 3 is that the two critical variables regarding classification of an item must be decided by two different agencies. The first agency must decide upon the tactical importance of the spare to the Battle winning potential of the force. The second agency must decide on the logistic implications of the item. Matamt B believe that these decisions should be made in isolation and that the criteria for classification should be decided by those most expert in Tactics and Logistics. Irrespective of the number of classifications from each, a matrix will be constructed which will then combine the two data and produce an individual priority code between 1 and 9

CONCEPT OF PRIORITY MATRIX

		TACTICAL IMPORTANCE						
LOGISTIC IMPORTANCE		1	2	3	4	5	6	7
	1	1	2	3	3	3	4	5
	2	2	2	2	2	3	5	7
	3	3	3	3	4	6	6	8
	4	4	5	5	6	7	8	9

Figure 4.17.

This code will then be used to influence management attention, procurement action, stockholdng, deployment and dispersal decisions. It will allow a greater degree of computer decision analysis which may lead to a far more efficient supply system. The concept is still very much in the embryonic stage but was being positively pursued (see Supply Branch Chapter 4.9.5).

4.9.3. HEERESAMT (Army Headquarters)

This element of the Heeres concentrated on logistics policy at C and D levels of Figure 1 whilst Matamt dealt with level B but are subordinate to Heeresamt. Levels C and D are still totally manual. As conscription still exists it is arguable that there is no reason to change. The Heeres found however that the number of errors through lack of effort could be overcome by installing computers and then using regular troops. There were many other instances but the standard argument for using computers, manpower saving, was not the overriding factor. Stock held at levels (C and D) are dictated by level B. Only those items authorised by Level B may be held. 60 days worth of stock is held at Level C and 45 days at Level D. Re-order point in both cases is 50% of stock and stock holdings are:

$$\frac{\text{Historical Demand + New Demand Period}}{2}$$

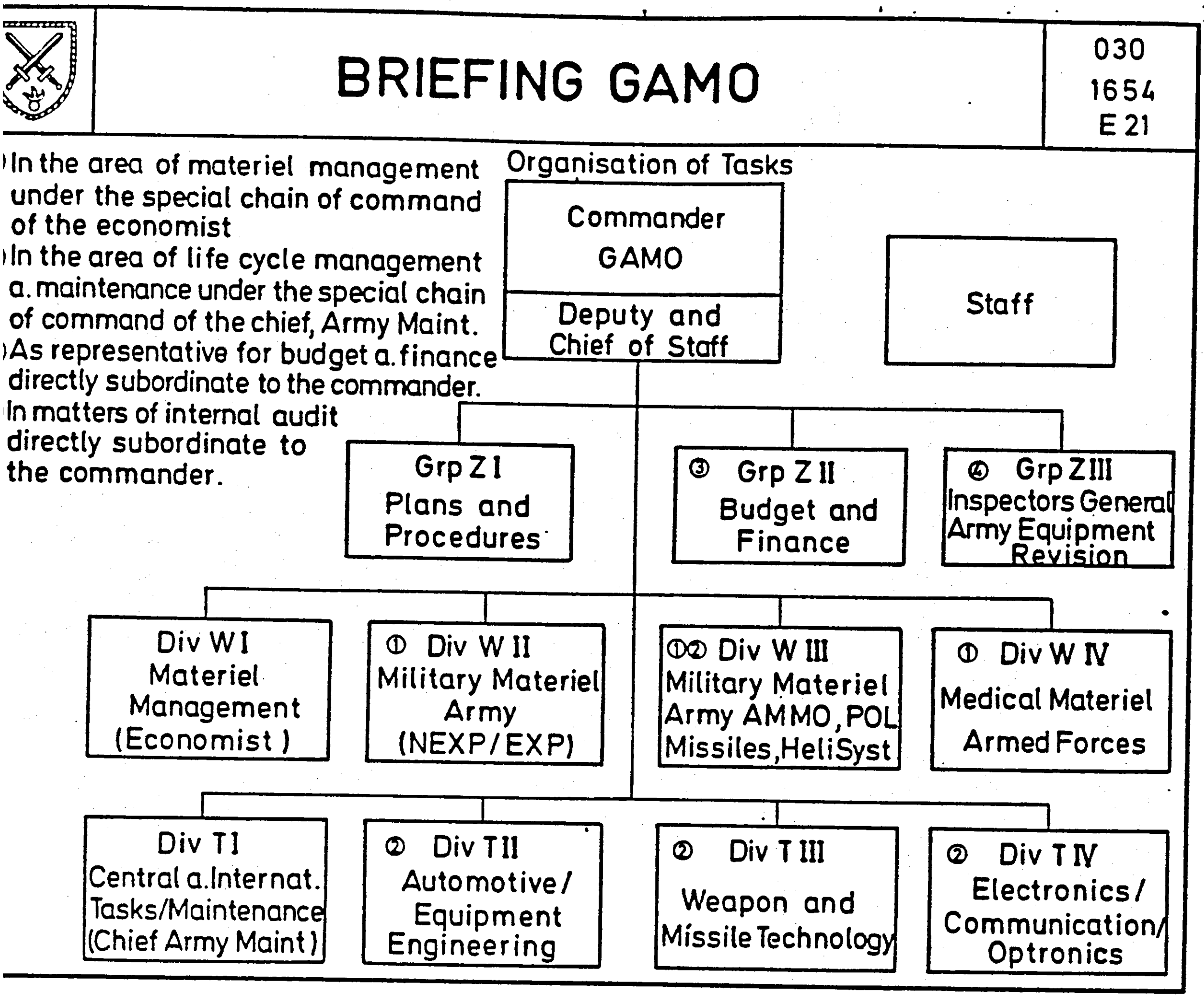
The expected Service Level is that every inventory stocking point will achieve an 80% first pass fillrate for the troops permanently assigned to its area (dependency) and 90% fillrate within 30 days. These figures are checked daily and summarised monthly. The figures were not available but it was suggested that the first pass figures were in the order of 65% with the figure rising to 80+ % after 30 days.

At level E, the customer, units are only entitled to carry very limited stocks of spares amounting to no more than 10 working days of stock. Whilst there is no direct inventory control or visibility of this stock Commanding Officers are held directly accountable for abuses of the Policy directives issued by the Heeresamt. This system was totally acceptable to the Germans because of their rigid ethical code.

4.9.4 MATAMT

The Matamt, which roughly equates to DSM(A) LE(A), and DSM(A) Divisions, is the centre for Heeres logistics policy within Level B of the supply chain. Unlike the British Army there is no requirement for Primary and Secondary depots and the regional depots are an amalgam of the two. Whilst overall Bundeswehr policy objectives with regard to logistics are disseminated from Bundeswehr (Matamt B), Heeres policy is produced by Matamt in conjunction with Heeresamt. It is intended that the policy element of the Matamt and the Operational Research element will move physically to Heeresamt in the future. An overview of Matamts location in the supply chain and its departments is at Figure 4.9.3. Matamt may, where it is the sole user, procure directly from NAMSA or overseas agencies (prior approval must be gained from Matamt B). The functional accounting elements of Matamt are the MKZ Truppe who are normally located in or close to the regional depots. This accounting element purely control and update the Inventory with consolidation of Heeres data taking place at Matamt. Co-ordination of Bundeswehr data from all the services is by Bundeswehr Matamt who in addition allocate spares after procurement is complete. Inventory control and forecasting is accomplished using normal ROL, EOQ and exponential smoothing techniques. Figure 3 illustrates the standard inventory concept. It was only after a series of questions that the real efficiency of the Bundeswehr became apparent. The policy constraints that had been authorised by the Bundeswehr allow considerable and possibly excessive stocks to be held. The holding period

FIGURE 4-1.


BRIEFING GAMO
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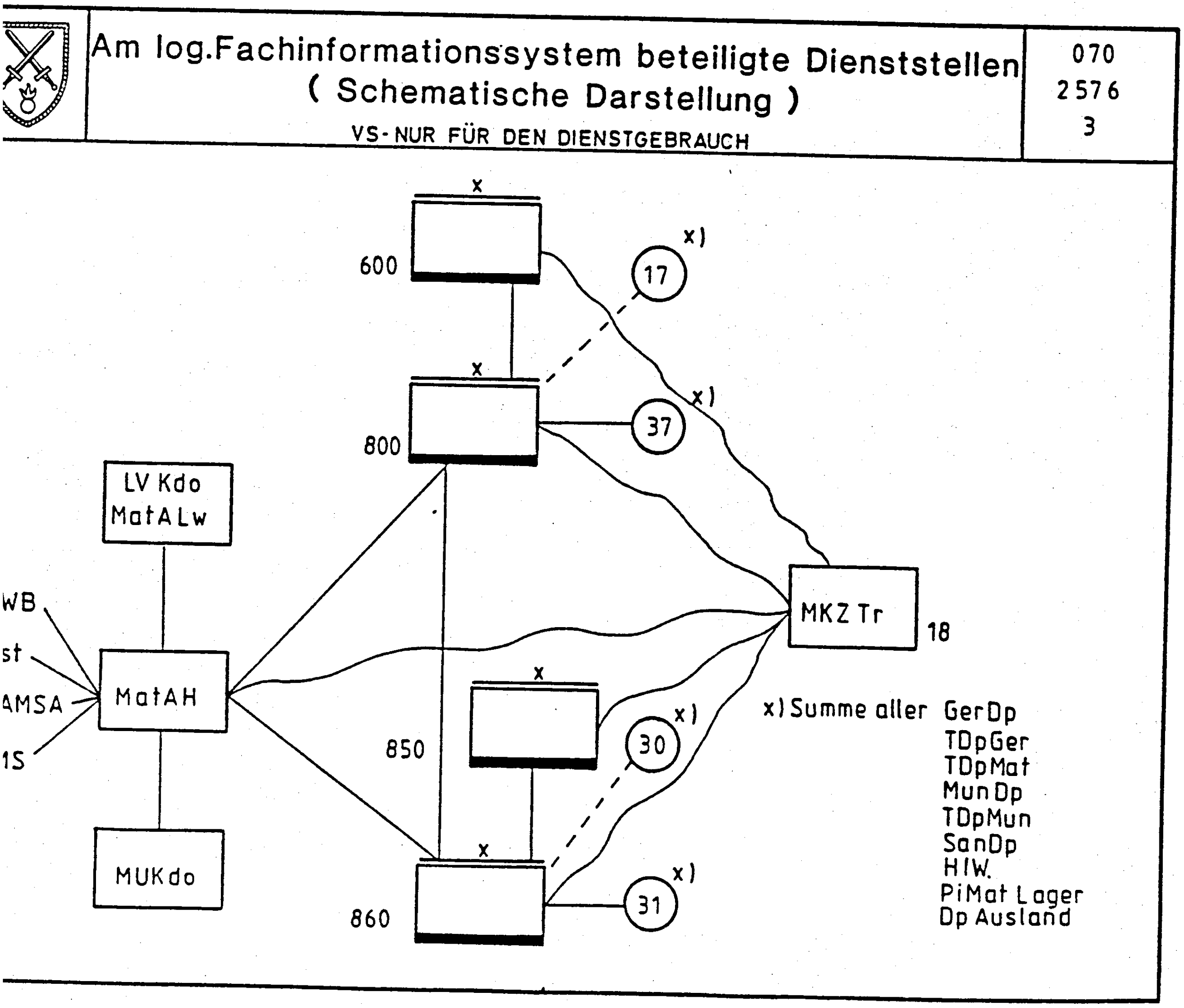
In the area of materiel management under the special chain of command of the economist
In the area of life cycle management a. maintenance under the special chain of command of the chief, Army Maint.
As representative for budget a. finance directly subordinate to the commander.
In matters of internal audit directly subordinate to the commander.
Organisation of Tasks
Commander GAMO
Deputy and Chief of Staff
Staff
Grp Z I Plans and Procedures
③ Grp Z II Budget and Finance
④ Grp Z III Inspectors General Army Equipment Revision
Div W I Materiel Management (Economist)
① Div W II Military Materiel Army (NEXP/EXP)
①② Div W III Military Materiel Army AMMO, POL Missiles, HeliSyst
① Div W IV Medical Materiel Armed Forces
Div T I Central a. Internat. Tasks/Maintenance (Chief Army Maint)
② Div T II Automotive/ Equipment Engineering
② Div T III Weapon and Missile Technology
② Div T IV Electronics/ Communication/ Optronics


Am log. Fachinformationssystem beteiligte Dienststellen
(Schematische Darstellung)
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TDpMat
MunDp
TDpMun
SanDp
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INVENTORY CONCEPT	075
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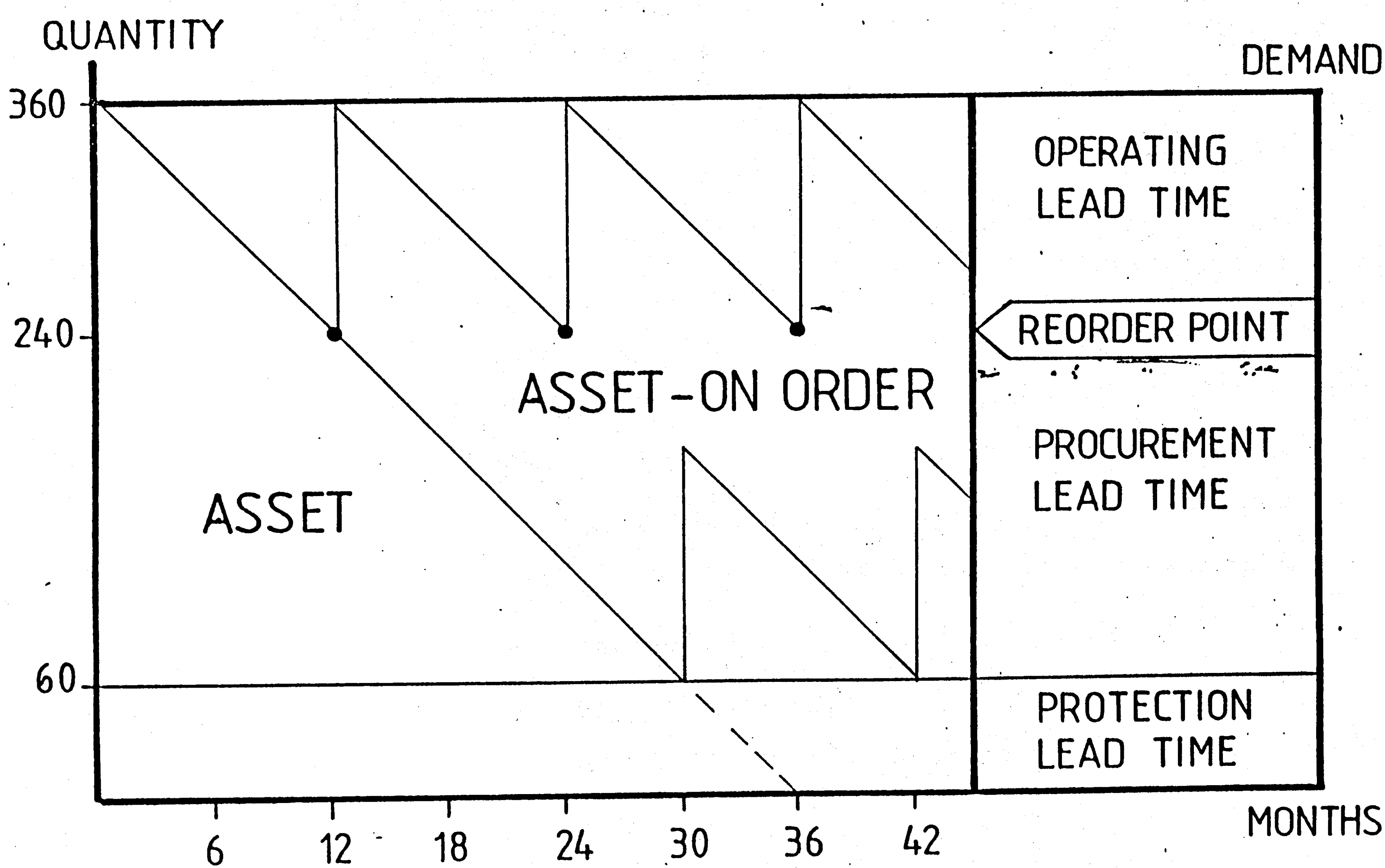


for operational stock within regional depots ranged from 1-7 years, the procurement stock from 6-30 months (but 3 months if the item was used by another service) and safety stock was fixed at 6 months. The authorised stock holding may therefore be in the region of 10 years*. Matamt are now under a remit from Bonn via Matamt B to investigate this situation and produce a study indicating where savings can be made. The section tasked with this study are GRP Z1. Their current objectives are to maintain 90% of tactical equipment at all times. Minimise the Inventory, minimise the workload, Maintain stock protection, EOQ manipulation and calculation, Economy of Distribution (Movement) and the availability of the reserves. To understand the size of the task it was necessary to ask how large the inventory was. The question sounds fairly simple and had been communicated and translated some months before the field trip (Annex A). The question was asked at every interview and a variety of answers were given, mostly contradictory. The following figures are therefore not substantiated. The total Bundeswehr inventory consits of some 3.5 million item headings, some are old numbers without stock, some are new numbers of valid parts but parts are not held, some are single service numbers only. Approximately 450,000 part numbers are in active use within the Heeres. Some 300,000 parts are consumable spares and 15,000 are repairables, the balance are non-moving. The 15,000 repairables represent in a Pareto analysis the A stock and the consumables the B & C stock.

The initial spares requirement for repairable items was carried out by stochastic methods but this procedure was only considered effective for between 5-6,000 item headings. The more normal method was the initial purchase or identification of a spare which may be required and the forecasting would use the standard exponential smoothing calculation. The present system has a manually adaptable constant of .3 or .4. It is the intention by 1988 to have a fully automated constant ranging from .1 to .9. The concentration on this variability of the constant is a fixation observed within other public concerns. There is a belief that with more responsive retrospective or less responsive retrospective tracking the forecast into the future will be more accurate. (This is discussed further in Paragraph 4.3.). Control of stock purchasing is again normal using the Harris formula

$$EOQ = \sqrt{\frac{2 \times Co \times R}{Ch \times P}}$$

The present level of Co is 500 DM* and Ch is .2. This should be compared with the present norms within commercial Inventory

The Matamt were extremely interested in critical spares and again had two clear variables. The systems importance to operations was the overriding variable, and the other was the criticality of procurement. The concept of system priority within vehicles was tanks at the upper limit with B vehicles (trucks) at the lower limit. Whilst it was con-

*Exchange rate when this figure was quoted was 3.15 DM to the pound.

sidered that spares within weapon systems were important, individual piece part spares would not be categorised, but sub assemblies would be. These sub assemblies would then come under a central control point under the command of Corps HQ. The only other form of priority coding that was under review would look at a system of automatic coding dependent upon the shape, size, weight and cost of the spare.

The maximum delivery time for all spares in the field Army area has been set at 14 days and requires a priority 13 demand. Authority to cross service from other locations requires a priority 06. The highest peacetime demand requiring instant supply regardless of cost is 03. German Army units may only use 01 and 02 during war. They do not use it, (unlike some other organisations) during peace. Demand priority for units is allocated using the FUD and UofN as in the British SPS. The exceptional difference between the two systems is that Schools/Training establishments are the highest priority in peace which is the exact reverse of the British system.

4.9.5. Supply Branch

The last visit of the Field trip was to what is generally regarded as the sharp end or coal face. In more formal parlance it is regarded as the Supplier/Customer interface. It must be stated here that the previous interviews were all conducted with Officers who whilst academically minded were in Tactical or Strategic Policy posts two or more steps removed from where actual operational policy decisions were made.

Oberst Hardemann who gave the interview had many years of experience in supply, was prepared to use modern computer technology but was in addition a realist. In his view he could see no logical practical way of improving the accuracy of the present forecasting system by introducing any different formulae whether they be based on life cycle costing, MRP or DRP methods or priority spares. His most serious concern was with the inflexible constraints upon the present system. It was his belief that far more efficiency could be achieved by educating, training and motivating his customers. He cited two classic examples which will not be too unfamiliar to any supply professional. During a routine inspection units are graded with regard to their operational readiness and these gradings are then produced in table form and units are compared with one another. The COs of units with most faults then instruct their QM (Purchaser) to disregard Supply Policy and ensure in future that they have less or zero faults. The second example related to incorrect demanding, through ignorance, and the cascade effect upon the system.

One unit at Level D demanded 1,000 lead Bombeln (lead security tags). The actual unit of issue was 100 so the demand became 100,000. By the end of the supply chain and procurement the Budeswehr actually purchased 30 million Bombeln. The customers motivation was suspect as he did not have to pay for his stock or his mistakes, neither did he understand the supply system or its operations. It was suggested therefore that the only way to improve forecasting was to develop the ability to control the customer in such a way as to smooth the demand profile which should also reflect actual usage. The staff however employed within supply were also a constraint upon the system. They tended to be young girls who could not identify with the spares nor had they the technical ability to question why it was being held and what it was used for.

The Heeres suffered from many random inexplicable demands which are not forecastable. An example was the M48 tank which had been in service for 25 years. Certain parts which had experienced no issues were only now being consumed. The parts are no longer available for purchase. Tactical policy changes also effected logistic policy. The M42 was declared obsolete and is now being run on in a different role for an extra 20 years. There are insufficient spares remaining within the inventory and spares are not commercially available. The service level to the customer will therefore be degraded, and the Supplies Branch cannot influence the supply. The additional constraint of random financial cuts is reducing stock in forecastable areas thus creating Dues Out. On receipt of stock it is promptly exhausted giving an overall impression of mismanagement. In order to rationalise limited resources the tactical command HQ have been requested by Supply Command to limit Tank track mileage from 1200 to 1000 Km per annum. This one decision would save 20 million marks each year. No decision has as yet been agreed. It is operationally important that tank crews are conversant with their vehicles and can fight them in all conditions. It is highly unlikely that total track mileage will be reduced.

The proliferation of new part numbers is swamping the ability of even the most highly trained supply operators using complex computer equipment. The Supply Branch have task forces operating to reduce Nato Stock Numbers. New technology, plus modification of old equipment with new elements is rapidly expanding the Inventory. The M48 had 8,000 parts Leopard II has 36,000. In 1974 the Inventory was 260,000 in 1987 it is 480,000. Policy decisions to remove inventory are taken whenever possible. For example all staff cars and light B vehicles are serviced and repaired at the main dealer agents. All self fit spares are supplied by main dealers with a negotiated discount. This policy extracted 20,000 NSNs from the inventory. Regrettably only 55% of the total parts required to cater for the Leopard II fleet!

DISCUSSION

The present Heeres inventory system, like most public sysems, is antiquated, operated largely by untrained personnel, is dependent for its efficiency on inflated budgets and is dictated to by both its ultimate customer and Tactical Policy. The present climate of change found at all levels appear not to be planned evolutionary change but change that has been forced upon the system by external circumstances. The decrease in real finance available to supply has been brought about by political financial stringency and the larger element of the defence budget which is now required to procure new systems. This has resulted in less money being allocated to supply from which more expensive parts must be purchased. The run-on of outdated equipments is perhaps the most worrying aspect of the external constraint. Had the supply system not been so over-cautious in the past the possibility of run-on could not have been contemplated, As it is possible the ability to reduce inventory holdings in many areas has now been lost. The changes that were most evident were the focusing of attention on those items within the inventory that were essential to operational capability. If identified then these items would be purchased first with the available funds before less important items were considered for procurement. The paramount logistic consideration was not the degree of supply achieved across the inventory range but the ability to maintain the operational capability of the Army in both Peace and War. The German chain of command is very clear, precise and logical. The Policy on control of inventory is well documented, efficient and out of date. The improvements to the system and the changes in inventory policy are unco-ordinated and fragmented. Separate planning is occurring at level A, level B and at Heeresamt for levels C and D. No single level is checking the effect of policy change upon the complete system. The main areas being considered for change are:

a. Reduction in stockholding.

b. Identification of essential spares.

c. Computerisation.

ANNEX A TO
4.9

BASE LINE QUESTIONS INVENTORY/FORECASTING

1. Inventory.

   a. Total NSNs

   b. Pareto Analysis.

   c. Live NSNs, Shadow NSNs, Civ NSNs.

   d. Life Cycle of Equipment,

   e. Civilian compatibility.

   f. Stock levels.

   g. Life Time Buys.

2. Forecasting.

   a. Present Methods.

   b. Past Methods.

   c. Future Methods.

   e. Actual Formula used.

   f. Variables considered relevant.

   g. Service Level total/Individual.

   h. Accuracy of System/Monitoring Method.

   i. Seasonal variation.

   j. Trend Analysis.

   k. Management Intervention.

   l. Policy tactical/strategic (Purpose of holding Inventory)

   m. Relevance of MRP/DRP.

   n. Constraints upon Forecasting.

CHAPTER 5. HYPOTHESIS

INTRODUCTION

5.1 In 1920 with nearly a million soldiers under arms the Ordnance inventory numbered some 20,000 item headings. In 1986 with roughly 165,000 soldiers under arms the RAOC inventory numbers some 740,000 item headings. This rapid increase in inventory size of some 37 times has not been accompanied by a corresponding increase in the methods of forecasting and inventory control, nor in the comparative measures available to assess the effectiveness of the high stocks and correspondingly high input of capital required to maintain such a large inventory. The current computer models used within System 3 are still largely reliant upon the Harris EOQ formula and the reorder point concept developed in 1915 and 1934 respectively. Whilst there have been striking advances in manufacturing inventory forecasting control with the implementation of MRP and more recently DRP, these advances have not been adopted by either the major public or private companies nor by the RAOC. Whilst the literature on forecasting and inventory control is legion there appears to be little effort by practising major companies to put into practice some of the thoughts and hypothesis of academics. This may partially be attributed to the fact that much of the literature work produces solutions to hypothetical problems as opposed to defining the practical problems and then producing solutions.

HYPOTHESIS

5.1.1 The hypothesis proposed is that individual parts, within an inventory, can be sub-divided by dependent, independent or both types of demand. Within these sub-divisions certain parts have greater significance and should attract more stock thereby reducing the risk faced by the Company. The majority of these spares fall into the dependent demand category and a classification process which differentiate between types of demand will improve forecasting and inventory control whilst reducing overheads and stock levels.

5.2 Classification/Identification. Chapters 3 and 4 identified classification/identification as being one of the more significant key points which had still to be achieved within the Distribution Field. The RAOC and all of the study companies have lengthy procedural steps which must be followed on the introduction of an item to the inventory. Drawings, specifications, codification, quality assurance and other steps must be completed and referred back to from the unique stock number of the part. These processes take months and in some cases years to complete and the manpower dealing with the steps can identify with each part. Once the process is complete the part increases in anonymity with the passage of time until it becomes just a number. The present RAOC classification system, along with similar systems elsewhere, goes some way to illustrate the individual value and management methods required to maintain stock levels. Regrettably no system exists to inform the management of the significance of the individual item. Stock forecasting and control systems are based on sufficient resources being made available to buy the stock predicted by the calculation as being required. If there is no money or no stock movement the decision making process is unable to cope and crisis management and intervention becomes the order of the day.

All of the systems that have been examined accepted that the maximum operability and in some areas economy would accrue from a workable classification system. Three companies favoured the approach that classification depended on an amalgam of tactical/operations factors and logistic factors. The major stumbling block was invariably that there was no clear ruling as to what was tactically essential, nor could more than two agencies ever agree a consistant batting order for equipments. The main thrust of all previous research has been to establish the tactical and operations factors which should be considered. On this question alone most of the research has foundered. The same problems that innovators such as Klausewitz and Guderian encountered have blocked most other attempts. This thesis therefore ignored, initially the tactical and operational considerations and concentrated on breaking the inventories down into sub sets which reacted to similar variables. The main variables considered are:

a. The use of the item heading.

b. The hierarchical role once used.

c. The means required to enable it to be used.

d. The causes necessitating its use.

e. The time lapse from issue to use.

f. The individual profile.

5.2.1. Each of these variables has been considered, in depth throughout the thesis but in summary:

a. The use of the item heading relates to its individual significance to the operation of the company as a stand alone part. This significance relates to the degree of effect upon the overall company strategy should the part be unavailable. Depending on the company role there can be 2 or more categories within this variable. The effect can relate to loss of profit, standing or inhibition of Mission. Whilst the degree of effect should be subject to risk analysis this is only necessary for those items which are clearly within the subset of greatest significance. It follows that the method of control and forecasting must be that producing the greatest degree of efficiency for those item headings held to be the most significant. The forecasting method is however unrelated to the significance variable.

b. Whilst an item heading may be part of a significant equipment its own role on that equipment may not be significant to its continued operation. The degrading effect of not having the item heading will relate to the classification of the part and the determination of the stockout risk acceptable.

c. The specialist tools, equipment and trained manpower represent the means which may be required in order that a part may be used. Additionally the need for other item headings, without which the item cannot be used, may require the use of BOM's which necessitate an MRP management system.

d. The identification of the cause of use should be the deciding variable as to whether an MRP or ROL type forecating system is used to manage the item heading. In its simplest subset the dependence of the item heading represents the initial variable.

e. The time lapse may or may not be a considered variable and will vary directly in relation to the companies operational and supply strategy. Its measurement and calculation will only normally be considered as a final segregation of important spares. Its impact on the company operation will be related to transportation, training and warranty.

f. The individual profile of the item heading need only be considered when an element outweights the other variables. Examples are:

(1) Lead Time.

(2) Shelf Life.

(3) Hazardous.

(4) Size, weight, shape.

HYPOTHESIS ANALYSIS

5.3. The reasons for holding inventory have been discussed at length in Chapter 3 and will not be discussed further. An inventory exists to support a particular environment and it is this environment which dic tates the types of demands which will be placed upon the elements of the inventory. Considerable work in the study has been carried out into analy sis of the demands placed by the environment and 3 states have been iden tified. These states relate either to the inventory as a whole or to part numbers as individuals. The prime state which was unquestioned for many years was that an item's demand pattern is totally independent. (Classification 2. Independent consumable.) If an individual item within inventory can emulate the life process surely the complete inventory must also exhibit the same reaction. There is a tendency, however, to automa tically assume that the total inventory will perform in a similar manner to the expected life cycle of an individual product, launch, life, death. This assumption pre-supposes a degree of homogeneity which is not found in all inventories. Homogeneity will be applicable to those inventories which are confined to a relatively simple range such as grocery items. The assumptions of homogeneity within inventory is however compounded by the process of stock control.

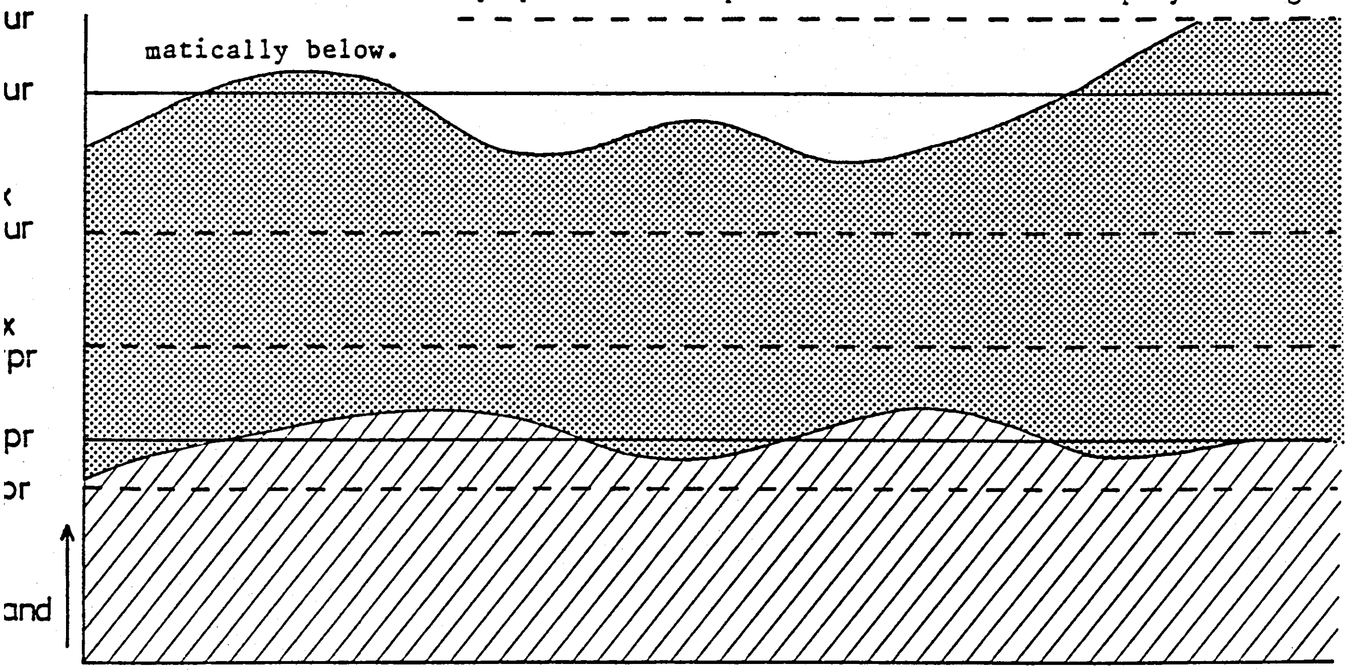
Within each group it is accepted that there are 3 classes of items, those regarded as A, B and C. The intepretation of A, B and C analysis was discussed in Paragraph 3.9.1. The basic premise however of the analysis is that each of these groups exhibits a different form of life pattern, either

active, semi-active or inactive. If we have started with the assumption that we have a homogeneous inventory we are then arguing against this assumption by the allocation of different life forms to three separate portions of the inventory we hold.
The larger the size of the inventory the greater the probability that there is actually more than one inventory which is being analysed. Whilst it is accepted that the measures of effective inventory discussed in Paragraph 3.8 tend to be true for homogeneous unique inventories, this failure to recognise multiple inventories leads to a distortion of the actual figures produced.

With increasing technology and engineering application to distribution science the second state that of a dependent demand was introduced and has been accepted, see paragraph 3.10 (Classification 1. Dependent repairable). Inventories could therefore be categorised into majority dependent or majority independent demands. This adoption of viewing inventory as a single entity was the third state. Forecasting and stock control was therefore carried out on either a dependent or an independent inventory in a single state. This division, the hypothesis argues is contentious because there are many items within the inventory and there will always be a sub division within the inventory between those exhibiting dependence and those exhibiting independence. Any single model will therefore cater for only part of the inventory. This inability to differentiate becomes critical when the item headings within inventory are diverse. There has been no sub division that could be found where anyone has divided the business world into classes in order that their inventory policy could be compared.

The most simple sub division would be active and passive inventories. An active inventory would tend to be an inventory which was maintained to actually generate profit whether by increasing sales or in direct support of a commodity already sold. A passive inventory would be the direct oppo site in that it is not sold but is maintained to support and be consumed within the company or business and is used to support the operation which in its own turn generates the profit or service which the organization is there to provide. For an active inventory the demand rate can be regarded as high and the turnover of part numbers (introduction and discontinuing of stocked items) is a constant throughput. The inventory may therefore be regarded as Live. It would be possible to sub divide these 2 classes into many sub classes but that is not the intention. The difference between the active and the passive inventory preclude a single or multiple type of policy which can be used with regard to all inventories. Both types however require formal policy planning in order to meet some hypothetical level of excellence.

Whilst the model, be it statistical, MRP or DRP based is quite capable of dealing with a single state it is incapable of coping with dual status. It is a natural progression therefore to identify that a fourth state can exist where there are clearly identifiable divisions within the inventory to create 2 separate single inventories within the whole. The argument of the hypothesis is therefore that to adequately forecast demand, inventories should be subdivided initially into classifications not by their physical make-up, nor by parts explosion, but by demand dependence. Stock control will still however require to be carried out in some logical numerical sequence and grouping which will still rely on part number categorisation. These individual inventories would be either independent or dependent for their demands (Classes 1 and 2). The second hypothetical state which may exist however is for an item heading to experience both dependent and indepen dent demands which when not isolated can be reflected as a single demand upon the item heading (Classes 3, 4, 5, 6 and 7). As inventories have grown larger and have covered much wider areas of product lines, it is arguable that there has been an increase in the sporadity of demand history. In the worst case in the largest of inventories the hypothesis argues that items can experience dependent demand, independent demand, a combination of dependent and independent demand and groups will exist within the inventory on which dependent demand is allied to a single or fleet of external equipments for operations. This is displayed diagram matically below.



Spares usage for scheduled planned repair (pr)

Spares usage for unscheduled repair (ur)
Time

Breakdown of Demand

Figure 5-1

The significance of this hypothesis is that irregardless of whatever forecasting system is used against the total inventory, it will only be partially accurate. From this initial hypothesis it would seem apparent that each individual item heading within the inventory must be analysed to ascertain into which category it will fall, dependent, independent or both. The argument for this supposition is the low success rate of inventory forecasting techniques which are based on single forecasting models (Chapter 6 see paragraph 2).*

The data from which these analyses are drawn are based on the single inventory concept and make no differentiation for the existence of multiple inventories. The Large Public or Private Company inventory, the hypothesis argues contains item headings whose demand is both dependent and independent. Neither of these is treated separately as the inventory is considered to be a single unique inventory. The inventory is however composed of unique item headings which exhibit different activities and their individual manipulation will have differing degrees of effect upon the physical cost of the total financial operation. There is little value in using expensive administration and management time in evaluating those item headings which have insignificant effect upon the total operation and whose cost may be measured in pennies. It is therefore argued that there should be an additonal category of inventory which may be regarded as insignificant from a costing point of view. (Classification 8). These items may normally be identified by ABC analysis. This argument could be further extrapolated to the point at which it is found that it is unnecessary to carry those item headings in stock as failure to supply will have zero effect upon the overall company operation. This Policy decision is a matter for the manage ment of a distribution system and is discussed further in the risk analysis section of Chapter 6.

Main Factors RAOC Inventory

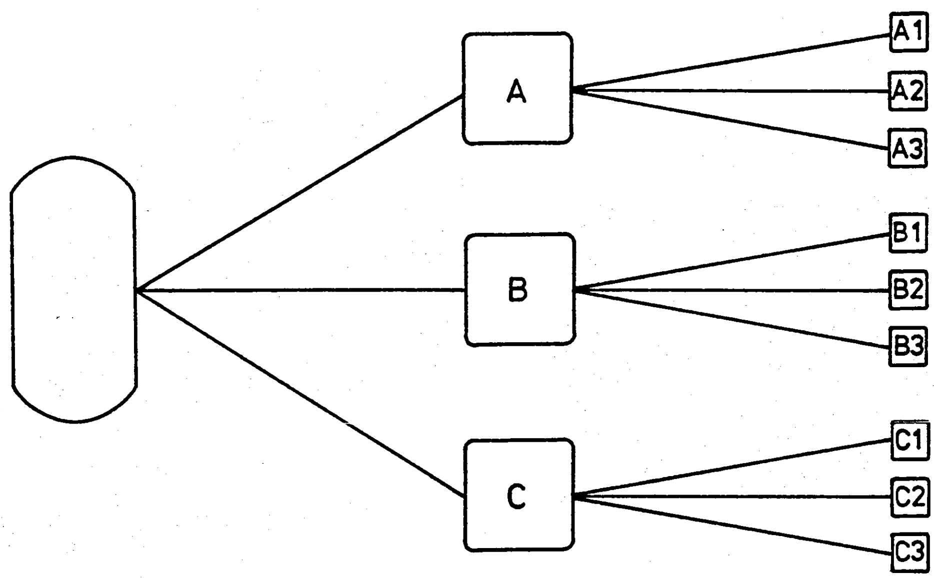
5.4. The characteristics of a unique item heading will allow the inventory to be categorised into various groups in which similar or like item headings are held. The major stumbling block with this fairly simple suggestion is that in the same fashion as Jekyll and Hyde could be one and the same person whilst being totally different, is that within most major public concerns there are 2 extremes which have to be catered for.

War Significance

5.4.1. In the case of the RAOC these are peace and war. An item heading may have little or no use during peace but be vital to operations during war and the reverse is also true. During peace the most significant characteristic of an item heading is the cost to purchase whilst in war the cost tends to be immaterial and it is the failure to supply which becomes the overriding factor. When the 2 are combined it is possible to draw the notional matrix which can exist in peace and in war. Such an analysis across the complete range of inventory would be impossible to carry out, even to do a small part of inventory would be time consuming and possibly counter productive. If however the problem is approached in a reverse manner it is possible to redefine the areas of inventory which should be analysed having removed already those item headings which need no further consideration. The 2 major factors which would be considered on the first trawl through an inventory should be the effect of a stockout (the War significance) and the possibility of an alternative source of supply (the Lead time element. To illustrate this point the decision over 2 part numbers 5120998045475 and 7830991385745, chosen at random, is relatively simple even without doing any research at all. The first is a wrench and may have some operational significance. The second is a vaulting box for gymnasium work. The effect of a stockout of a vaulting box during war would be nil and should such an equipment be required various alternative sour ces of supply could easily be found. The wrench on the other hand may be part of a complete equipment schedule and may be classed as opera tionally essential. If there are several other wrenches capable of performing the same function within the inventory, it would only be necessary to classify one of those item headings as essential for war and to be maintained in a no stockout position. This first trawl coupled with the data already on file will allow the 8 classifications to be allocated.

5.4.2 Volume by Value

The major stumbling block with any major organistion is the sheer size of the inventory and the time that would be required to identify the various elements which it is considered should form part of the decision matrix. Assuming the fact that any organisation whether profit or service motivated must operate within finite resources then it is accepted that 100% availability for the complete range of inventory is an impossible objective. Money tends to be the governing restraint and the hypothesis agrees with the present attitude within distribution that this should form the second point for analysis. Where the hypothesis differs from accepted practice is that with the vast number of item headings held a straight forward ABC ana lysis is considered of little real value. It is proposed that prior to analysis the inventory is subdivided into high value, medium value and low value items. It can be argued that a double ABC based on throughput and then value caters for this problem but the contention is that with



Multiple ABC Analysis
Figure 5.2

large inventories, the sheer size leads to a blurring of the division between A and B and possibly C and that the value of the process is negated. Assuming for the moment that this is correct the value of the effort required can only be optimised if the analysis is taken one stage further. The degree of effort in this next stage may be limited to the three categories of A or if resources are available cover the nine categories of A, B and C.

5.4.3. Lead Time

Failure to supply caused by insufficient stockholding can have dif fering degrees of effect on the companies operation. At this point they may be loosely termed High, low or nil effect. This argument is not new and has been covered by a few authors when related to spares parts inventories. The major difference with prior work and the hypothesis is the argument that all items within complex inventories within the A category should be assessed for their effect on the operation. The normal approaches postulated in the past have proposed three or at the most four subdivisons of risk nearly always based on perception or cost. Stockout the hypothesis argues is not the governing factor but the time to replace stock must be the overriding constraint. The actual as opposed to the management related lead time to replace stock should be the governing factor in assessing what constitutes a stock out risk. Companies A and E have already adopted, dictated by circumstances as opposed to actual con sideration, a system that is not dissimilar to this and is covered in Chapter 4. With the opposing operating conditions of Peace and War the possible alternative sources must also be considered. The only variable which cannot be directly quantified is the change in usage from peace to war. Fortunately, from a humanitarian viewpoint, the British Army has fought no major conflict since 1945. This however means that the decision process on War Reserve spares is based on con jecture, simulation, conflicts fought by other armies and to some extent pure guesswork. This variable however should be brought into its correct context. Whilst the requirement for combat supplies and replacement equipments represents a major financial commitment the present holdings of war reserves represent some 1.79 percent of the total inventory value. The significance of this point is perhaps best illustrated by the usage of Rapier spares during the Falklands war. The limited number of equipments committed to this operation used 18 months worth of the total war reserve for certain spares in a matter of 6 weeks. The hypothesis therefore proposes that if war reserve spares cannot be calculated then the peace holdings should be increased to such a level that the failure caused by increased usage in war is negated by increased stocks in peace. The hypothesis suggested therefore is that the Service level of all stocks should be dictated by their operational importance. The increased level of war reserve spares being funded by the respective decreased levels of stock for non-operational spares.

5.4.4. Repair Time.

The RAOC divides its inventory into general stores, clothing, MT and technical stores ranges. The item headings within these ranges are divided into complete equipments, repairable assemblies and expendable stores. Complete equipments and repairable assemblies are not controlled by forecasting techniques but are dependent for their holding and repair on the fleet or dependency which they support. The stock balance of the inventory, some 740,000 item headings are controlled by a single forecasting calculation which depends upon usage. This system is mirrored by Companies A, B and C albeit with differing terminology. Commercial firms whether public or private tend to refer to consumables and repairables and include the complete equipments as repairables. The focus of management effort tends to fall on the repairable item headings with control of consumables being left to whatever computer programme has been installed. The obvious reasons for this subdivision of effort is the visible cost not only in initial purchase price but in maintenance workshops and manpower. In addition the failure of a repairable item heading, be it an aero engine, a mine water pump or a tank engine appears far more important than the shortage of a turbine blade classed as a consumable. The lack of or shortage of turbine blades over any period of time may not be catastrophic but once this shortage has forced all of the repairable reserve assemblies to be used then the effect will be the same as a shortage of repairables. The hypothesis therefore is that every consumable must be categorized with cognisance of its effect on its parent equipment and its parent equipments position in the hierarchical workings of the establishment. For a private concern this is a far simpler matter than for a public concern. The effect of downtime of an equipment can be quantified to a greater degree than for a public organization. That is not to say that public concerns are not motivated by profit! A public concern such as Company B relates the component parts of an aircraft, some of which may be regarded as individual equipments, against the effect of failure on the safety of their customers. An aircraft seat fulfils not only a comfort role but an element of the overall safety of the passenger. One seat however is not accorded the same significance of an engine or a navigation system. The plane can fly one passenger short and still perform its function to an acceptable degree. The shortage of functional seats only becomes a problem when sufficient seats are unserviceable to make the planes journey non-profitable. This situation may still not be considered as an emergency as it may still be sufficient, dependent on demand, to operate the flight in order that the standing of the company is not impaired. This analogy has been introduced in order to demonstrate the proposed deterministic/stochastic process which must be followed to categorize a spare. The sequence of steps is arguable but if you are the individual concerned then the effect on the individual is paramount. The second element is the effect on the equipment and its capability of performing its primary function. For private concerns there is only one additional element and that is the effect on the corporate body. For many public bodies dependent on their status or role there is the additional element of the effect on national interest.

Hypothetically therefore there are four elements which should be considered when examining the importance of a spare. If one were only considering a peacetime situation these four would suffice. The importance of human life during war is however subservient to national interest. The RAOC inventory is maintained in order that the United Kingdom can fight and win a war. This consideration must therefore temper our analogy and the importance of the individual. Of more importance is the role an idividual is expected to perform. The first element should therefore concern itself with the effect on the ability of the individual to carry out his role.

Having deduced the effect of a shortage against various levels there are two other considerations which need to be examined. Both relate to time. The first relates to the time elapse between the requirement arising and the part being supplied which we will refer to as the customer lead time (CLT). The second element of time is the time to fit or bring into use the spare supplied which will be referred to as the repair time (RT). These times will vary for each individual component and will also be dependent on the ability of the engineer fitting the part (TRG), the conditions (C) he must work under and from where the engineer (ET) has travelled. The total time elapse in its simplest format would therefore be:

$$CLT + RT^{(TRG)} + RT^{(C)} + ET = TT.$$

The major elements within this formula will be CLT and $RT^{(TRG)}$ as the increase incurred by $RT^{(C)}$ and ET will normally be small. In peacetime all capital equipments are maintained in service by repair and are subject to disposal on economic grounds. This standard is maintained by both the public and private sectors. In war priority would be given to those equipments which can be repaired quickly and which have a kill or defensive potential. There would therefore be an element of queueing of equipments dependent upon the speed with which they can be repaired and their individual importance. This was tried and tested by the Israelis in both the 1967 and 1973 wars. The additional element will therefore be Priority Time (PT) which may range from 0 to infinity. The inclusion of infinity is necessary as parts may be removed from a casualty to repair high priority equipments. The final equation will therefore be:

$$CLT + RT^{(TRG)} + RT^{(C)} + ET + PT = TT.$$

From the organizational structure and explanation of the Standard Priority System in Chapter 2 paragraph 2.6 it is fairly obvious that CLT can have five variables. These are:

CLT_1 time elapse from unit to customer

CLT_2 time elapse from Ord Coy to customer

CLT_3 time elapse from FOD to customer

CLT_4 time elapse from COD to customer

CLT_5 time elapse from manufacture to customer

Each variable will additionaly be affected by the travelling conditions during tension, increased hostilities and war. Whilst all parts that have been known to have failed or are expected to fail are held in CODs only those parts which obey the following should be held forward in peace.

CLT + RT(Trg) + RT(C) + ET = 48

This initially appears to be a contentious statement but should be examined after considering the general Equipment Management policy Statements. These lay down an expected availability of x% during peace and y% after 24(note 1) hours of tension and close to 100% after 48 hours. Therefore the relationship of CLT to RT(Trg)+RT(C) + ET will approach a straight line graph.

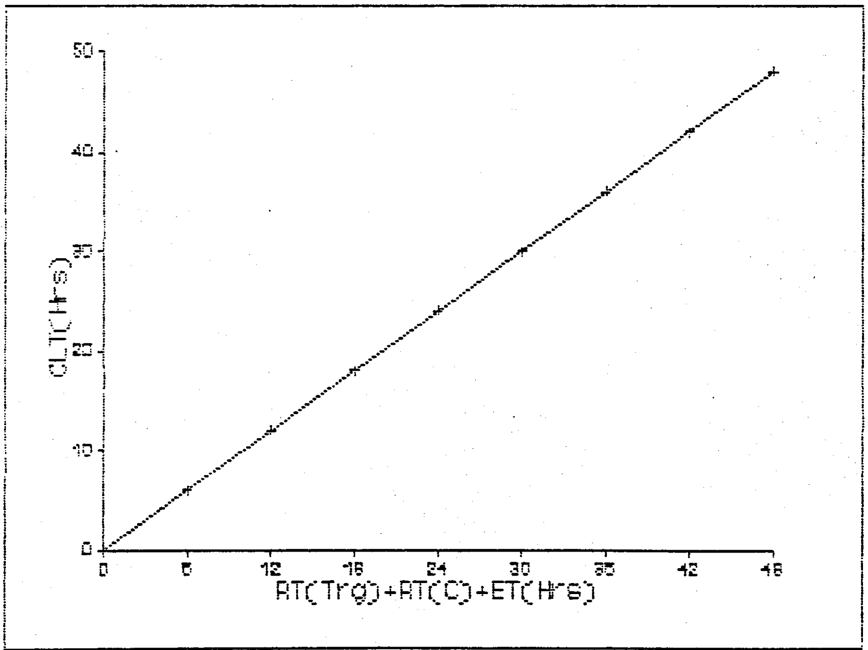
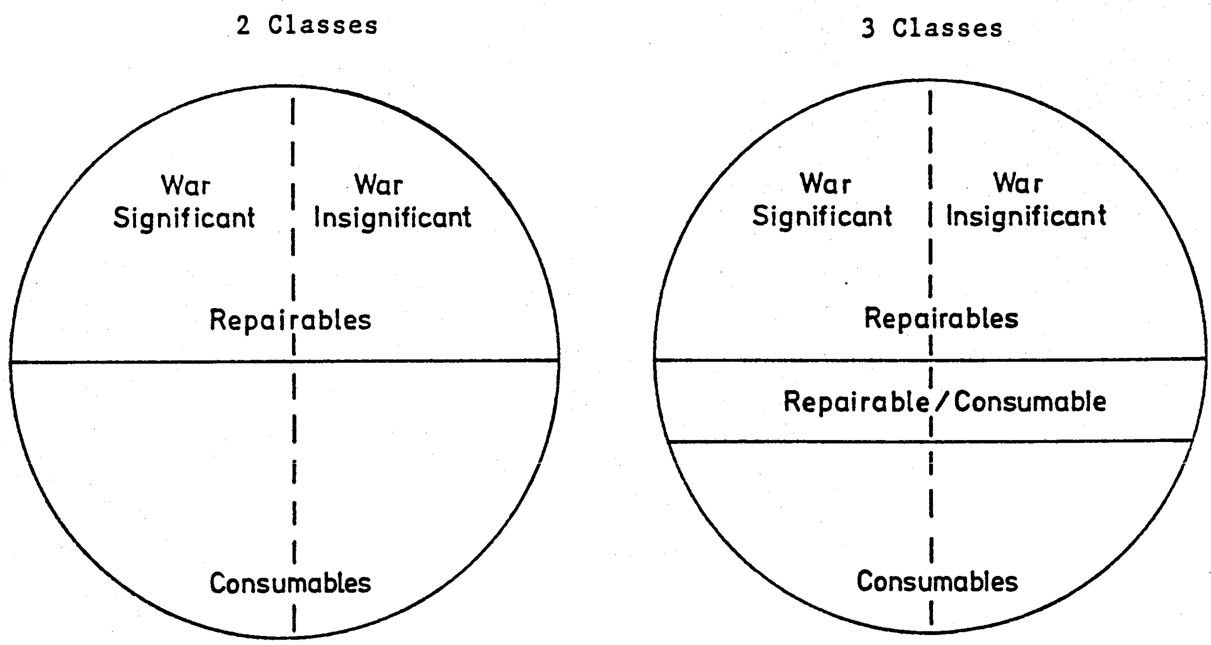


Figure 5-3
Relationship of Repair Times

Note 1. This is shortly to be changed to 48 or 72 hrs.

5.5. Trial Hypothesis Classification. The hypothesis however argues that rather than establish rules and variables for the significant element of the inventory the first step should be the identification of that inventory which is insignificant when only the primary purpose of holding inventory is considered. In the case of the RAOC this is of course war. The inventory should therefore be first assessed for its war insignificance.

All inventories researched were already in a position which would enable them to subdivide their item headings into consumable and repairable. Invariably there is some blurring of this classification and the consumable/repairable classification is normally introduced. The second process therefore is to identify all war significant parts in the two or 3 classes



Classification by Classes

Figure 5-4

The value behind this approach is that whilst a non-technical individual would have some difficulty identifying a war significant item heading it is possible to identify war insignificance. A simple set of guidelines can be written by the inventory managers within each inventory group to ensure this was succesfully completed. The first pass would remove over 50% (350,000) of the present item headings. This would have the additional advantages of ensuring that management time was concentrated in a much smaller area. This should ensure that the upper levels of classification are more accurate. The present demand/usage must be ignored at this point as it is largely irrelevant as it is drawn from usage during peace. It is essential that the classification process identifies significance for war. If the non significant sweep is effective then the remaining stock must be classified with regard to Lead time, Supply chain time and Repair time. The lead time currently shown on the computer will drastically reduce during war when the countries industrial base and workforce focus on patriotism and survival. The scenario for war is however a short tension period followed by a brief but vicious battle. RAOC stock is held against the accepted scenario and therefore the total stock required for war should whenever possible be held or on order. The current lead time is therefore the one that should be used, this does not however infer that the shown lead times cannot be further reduced in Peace. In order to allow some form of grouping

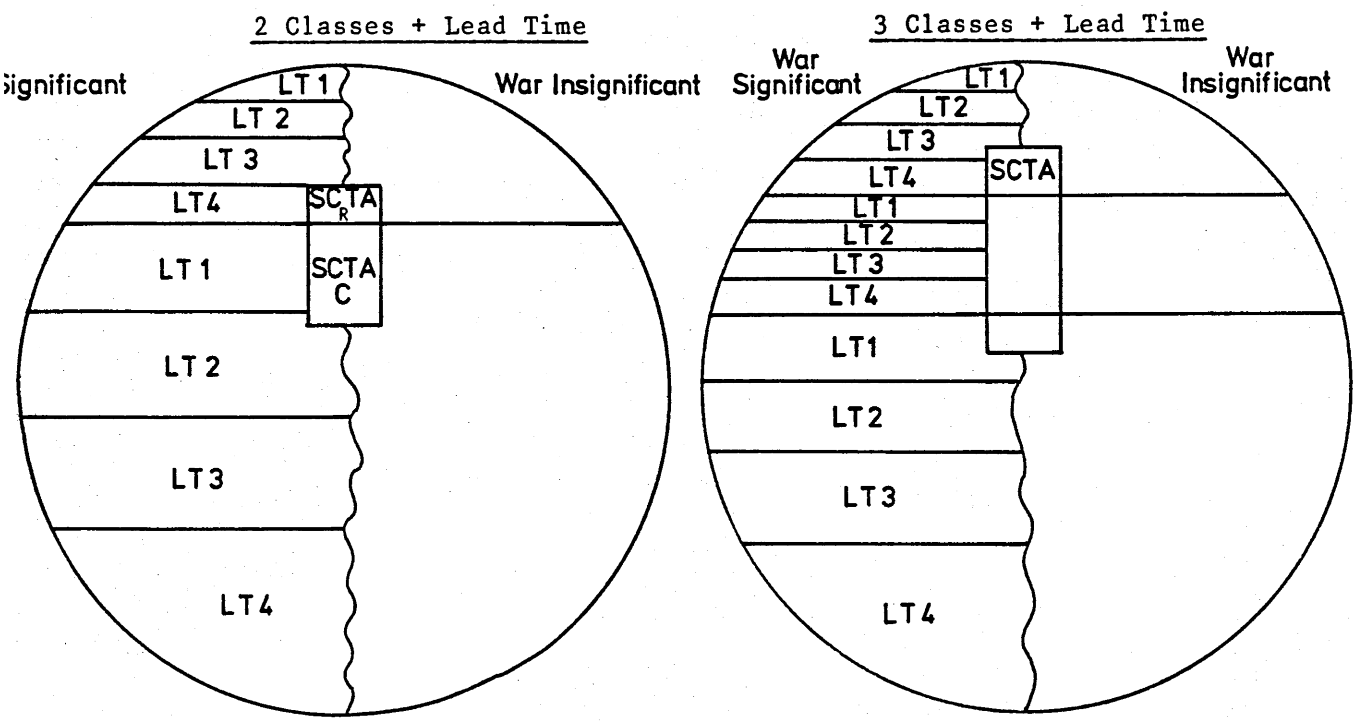


Figure 5-5

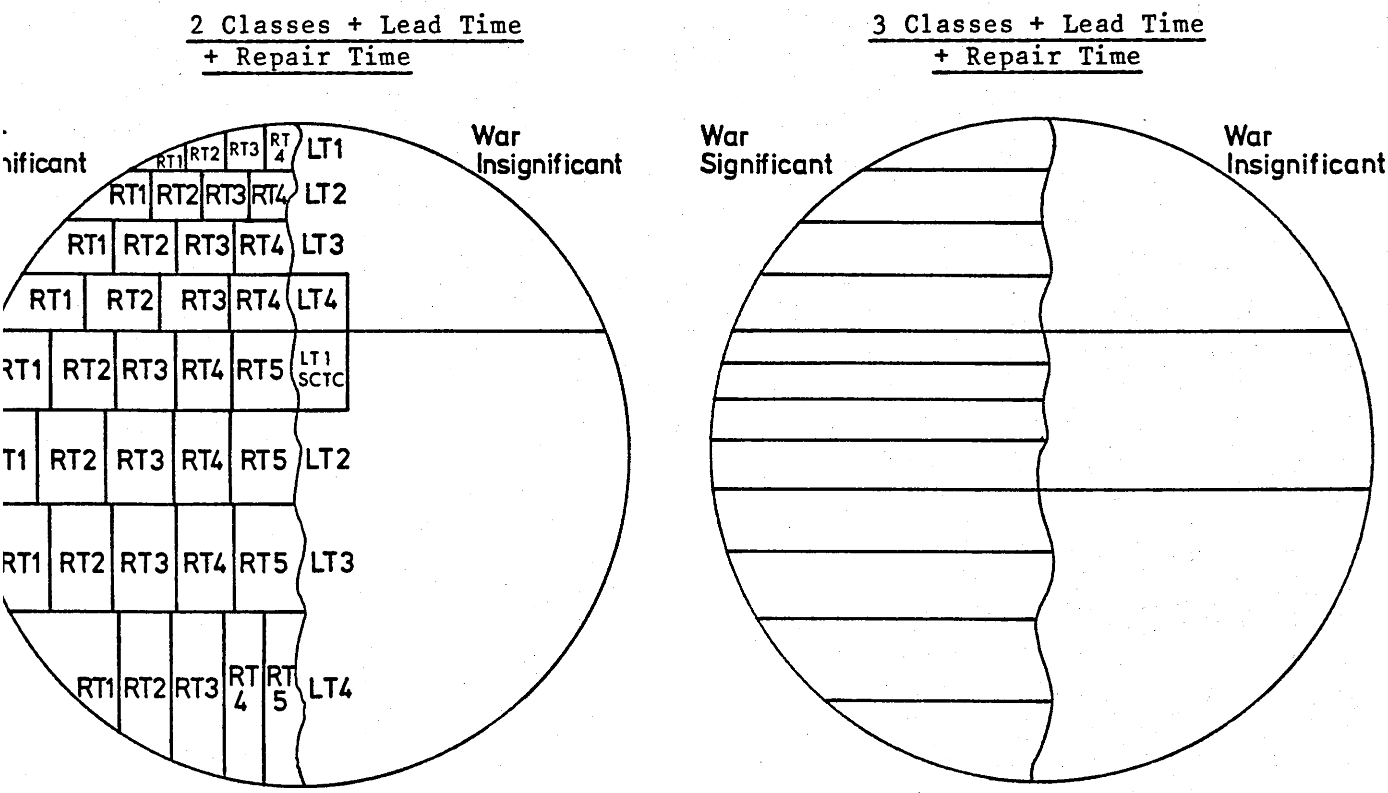
the initial classification it was decided that the lead time groups should be:

LT1	6 months	
LT2	6 months	12 months
LT3	12 months	24 months
LT4	24 months	

The supply chain time does not differentiate between consumable or repairable and, in war, cost is of no consequence. The time therefore for a war significant item heading will be the fastest possible, subject of course to hostile interference. The equipment the item heading relates to is not important, what can affect the supply chain time however is the item itself. Size and weight necessitating special handling facilities may increase the travel time and whilst not requiring an additional classification will require different supply considerations relating to positioning within the supply chain. The only other factor within this area to be considered is hazardous cargo. Where the item will require special handling or must be isolated from other items the timings again will be severely affected. The supply chain time, it is believed might be ignored as for all but a few categories it will be the same. A special classification however should be established for items whose unique characteristics will affect the standard supply chain timings. This category will be referred to as SCTA (Supply Chain Time Affected).

The third area which requires consideration is the repair time. This is covered in detail in paragraph 5.4. The repair time for a consumable can obviously range from 0 for a spanner which is a non-related item heading to several days for a crankshaft bearing in a tank engine. Within the repairable category the repair time cannot start at 0 but again can be up to or in excess of several days. In the given war scenario the most crucial stages will be achieving maximum operability before hostilities commence and then maintaining operability once battle casualties are suffered. The most important categories for repair time should therefore be the shortest. The following repair times will be considered to examine the relevance of repair time.

RT1 = 0 (Consumables only)
RT2 > 12 hours.
RT3 < 12 hours > 24 hours.
RT4 < 24 hours > 48 hours.
RT5 > 48 hours.



39 Classifications 55 Classifications

Classification by classes Lead Time and Repair Time

Figure 5-6

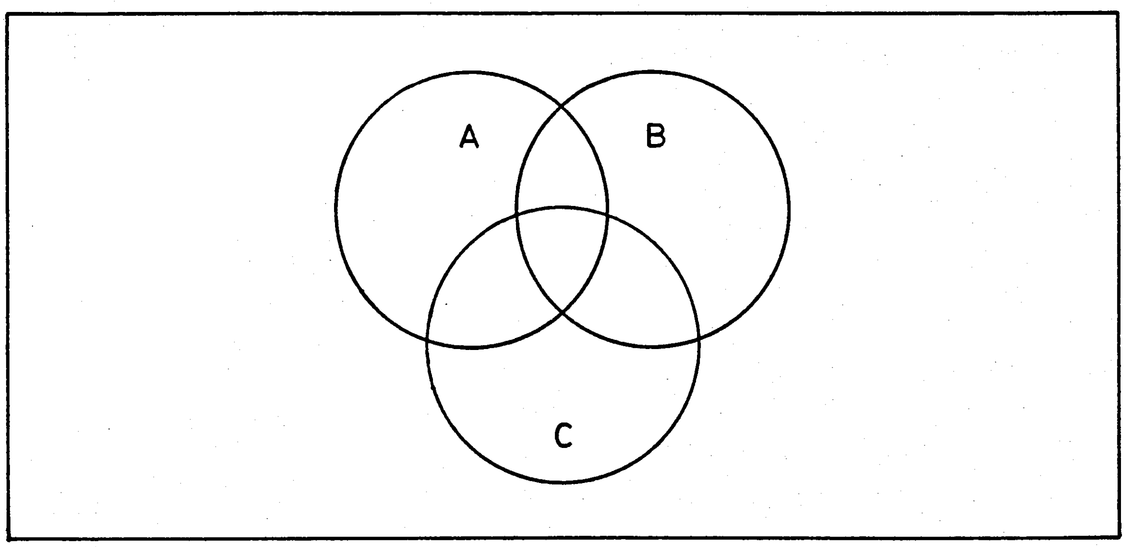
In figure 5.6 the number of possible classifications for the 2 systems are 39 or 55. As soon as this level of definition is reached the user of the system tends to become confused and the system loses both credibility and use.

Even on the small samples of data each item would have to be matched against a minimum of 7 configurations before it could be classified. If the major variables are:

1. War Significant
2. War Insignificant
3. Repairable
4. Consumable
5. Both Consumable and Repairable
6. Lead Time
7. Repair Time

then it is possible to allocate the possible sets which are displayed in the Venn diagram below.

War Insignificant



Venn Diagram

Figure 5-7

A represents the set Dependent, Repairable, Repair Time
B represents the set Independent, Consumable, Lead Time
C represents the set Independent, Dependent, Repairable, Consumable, Movement Time

Note 1. Total area represents complete Inventory.
2. Area occupied by circles does not represent group sizes of sets.

The 8 possible combinations would be:

1. AnB'nC' Sig Dependent Repairable Repair Time
2. A'nBnC' Sig Independent Consumable Lead Time
3. A'nB'nC Sig Independent Dependent Consumable Repairable Mov Time
4. AnB'nC Sig Independent Dependent Consumable Repairable Mov Time Repair Time
5. A'nBnC Sig Independent Dependent Consumable Repairable Mov Time Lead Time
6. AnBnC Sig Independent Dependent Consumable Repair Mov Time Lead Time Repair Time
7. AnBnC' Sig Independent Dependent Consumable Repairable Repair Time Lead Time.
8. A'nB'nC' Insignificant Independent Dependent Consumable Repairable

If the Pareto rule of usage holds good for stock quantity during war, and there is no evidence to suggest it does not, then 80% of the inventory will lie in A'nB'nC'. This will therefore mean that the actual level of inventory requiring classification should be in the order of 150,000 item headings. If the items were evenly distributed amongst the combinations each combination would hold 20,000 items of inventory. As the business norm is taken as 12,000 item headings per provisioner the working inventory could be handled by 14 professionals.

5.6 Comparison. There is a constant requirement whenever government funds provided by the taxpayer are consumed to ensure that what is spent is utilised in the most effective way. Whatever can be saved or where malpractice can be identified, action can be taken to reallocate resources for more demanding or essential priorities. Defence spending will always be under scrutiny in peace and this examination becomes even greater when all government spending during periods of financial restraint are under scrutiny. Measures of efficiency can be produced by two opposite methods. Firstly the efficiency of a system to meet the internal objectives set by higher management provides the most precise method of gauging a systems efficiency. Commercially this is the most practical and useful but relies on the clear management understanding of what they wish the system to achieve and then being ableto communicate these wishes into clearly understandable objectives/ targets or policy. The second and increasingly more important method of measurement is by direct comparison to other companies. This comparison is often carried out with no regard to similarity of operation or constraints.

SUMMARY OF HYPOTHESIS AND EFFECT OF IMPLEMENTATION

5.7. Classification. The process of classification will enable the inventory to be divided into subsets of homogeneous items which will react in demand patterns, cost, usage or a selection of variables which having been identified will react to alternative systems of control especially the application of ROL/ROQ systems, forecasting calculations or policy parameters. This may allow if the hypothesis is correct:

a. Reduction in Stock Levels.

b. More accurate forecasting.

c. Increased automation.

d. Closer computer management control and flexibility.

e. More accurate compilation of budget costs and forecasts.

f. Increased management data.

g. Greater simulation of options.

5.8 Multiple ABC. The multiple ABC analysis should allow:

a. Concentration of management effort.

b. Decrease in stock outs of fast moving spares.

c. Decrease in management effort on unnecessary items.

d. Decrease in output of insignificant data.

e. Increased control over budget and spend.

f. Incresed awareness of inventory problems.

5.9. Repair Time. The introduction of Repair Time calculations related to inventory will have the following effects:

a. Increase in stock within Theatre.

b. Decrease in stock levels in UK.

c. Decrease in overall war stocks.

CHAPTER 6. DATA SAMPLE

6.1 Introduction. Drawing data from any inventory belonging to a multi-national combine poses certain problems. If the sample is too small any result is open to criticism as being unrepresentative. If too large the sample becomes unwieldy and tests become increasingly difficult to carry out or bring to any conclusion, it is also possible that vital results are overlooked in the mass of data created.

An analysis of complete inventory is as meaningless as an analysis of an individual part when that inventory numbers some ¾ of a million item headings. The two analyses together, it is believed, will give both the micro and macro overviews of the state of the inventory and the possible benefits or not of a change in line with the postulated hypothesis. It is not possible to state how far one has gone without knowing where the start point is. The first part of the chapter investigates the present state of the inventory. In the second part random samples have then been taken and the hypothesis tested against them to see whether there is a negative or positive effect. The tragedy of any work of this nature is however that unless the actual results are superimposed in a real world and all the constraints come to fruition (that is total war) then the true as opposed to calculated effectiveness of the changes will never be known. Validation and the effects of change have been calculated as far as humanly or humanely as possible (Note 1).

Note:

1. Parts of the thesis are now being implemented. These are detailed at Chapter 9.

It was decided at an early stage that it was both unmanageable, unnecessary and practically impossible to carry out analyses on each item of the total RAOC inventory of 740,000. It is a live inventory and roughly 2% of the inventory would have changed during analysis due to obsolesence and inscaling. In order that the analyses were as accurate as possible the two major aspects, present state and the effect of alternative procedures would require differing samples. In order to analyse the present state the inventory was analysed using the present Domestic Management Code groupings.

<u>6.2. The Present State</u>. This analysis used readily available data from the RAOC Management Information Returns (MIR's). The only method of ensuring totally acceptable accuracy was to take a one-off snapshot of the total inventory holdings. This would allow the reliability and efficiency of the present system to be graded against the Domestic Management codes. A one off MIR was produced by DSM(A) listing the following data:

a. Total NSNS in DMC.

b. Total NSNs with no movement in 3 years.

c. Total NSNs not exceeding tracking limits.

d. Total NSNs breaking tracking limits once.

e. Total NSNs breaking tracking limits more than once.

The inherent problem with a snapshot sample being that whilst it represents the whole population it may not be representative of the average situation.

With an inventory of ¾ million and an offtake of 3 million issues per annum however the aggregated average tends to the norm. This has subsequently been quantitatively analysed by carrying out the same tests using a snapshot at yearly intervals over 3 years. The results support the initial findings.

6.3. Alternative Procedures Sample. The critical samples for analysis were taken at random but in 2 ways. The split between COD's Bicester and Donnington is by DMC and therefore separate samples were taken from both Depot holdings. In order to have an independent sample, a sample was also taken from the complete inventory. This third sample was supplied by the RAOC OR cell and was used to confirm the validity of System 2 and 3 Systems. The Domestic Management Code attempts to group items belonging to types of equipment or having similarities of use. These DMC's represent a stratification of the inventory. DMCs range from 10-50 items to 10,000-15,000 items. A random sample from each approximating to 1% of the NSN's per DMC was taken. Where 1% yielded no sample the DMC was assessed. If the NSN's were active and were not new to service a sample was included. Whenever the NSN's were unestablished i.e. a new DMC these were ignored. After selection of the sample NSNs, Provision Review Form (PRF) [Note 1] output was requested from DSM(A) and the following data loaded onto a Sirius Micro:

NATO Stock Number

Domestic Management Code

Item Name

Inventory Classification

Service Level Achieved

Service Level Required

Establishment Date

War Maintenance Reserve Holding

12 x Quarters Issue Data

Control Indicator

War Reserve Stock

Forecast Quarterly Demand

Last Issue by Date

Lead Time (Management Set)

Lead Time (Computer Calculated)

Re-Order Level

Economic Order Quantity

Price per Item

Stock Holding

Note: 1. An example of a PRF is at Annex A. The data was loaded manually twice and cross checked. PRF's were retained in case unusual results required checking at a later date.

6.4. Present State (Macro)

The published efficiency of the present forecasting and inventory control system is based on the achievement of a 95% service level. This service level is adversely affected by natural and imposed constraints, discussed in Chapter 2. The structure of the present database subdivides NSN's into:

1. Recurring Demand (RD)
2. Management Level Established (MLE)
3. Management Level Unestablished (MLU)

Within System 3 stable computer controllable items are referred to as Recurring Demand (RD) items. When an item is introduced into the inventory or when it becomes unstable its status is Management Level (ML).

From the available data this can be further subdivided into:

1. a. Recurring demand not breaking tracking limits RD0

   b. Recurring demand breaking tracking limits once RD1

   c. Recurring demand breaking tracking limits twice RD2

   d. Recurring demand with no movement RD

2. a. Management Level established not breaking tracking limits ML0

   b. Management Level established breaking tracking limits once ML1

   c. Management Level established breaking tracking limits twice ML2

   d. Management Level unestablished with no movement MLU

   (note MLU breaking tracking limits included in ML1/ML2)

This produced 9 fields from which the following data was compiled:

NSN Total	RD0 + RD1 + RD2 + ML0 + ML1 + ML2
NSN Nil Movement	MLU + MLE + RD

NSN Movement   NSN Total - NSN Nil Movement

Total Tracking Limit breaks(TRE12) = RD1 + RD2 + ML1 + ML2

Total Tracking limit two break (TRE2) = RD2 + ML2

The efficiency of the forecasting system was taken as the number of line items experiencing movement which did not break the tracking limits. This was taken at two levels. Level 1 efficiency with 1 break (EFF1) and level 2 efficiency with two breaks (EFF2). The equations used were:

1 $\frac{\text{NSN Movement} - \text{TRE2}}{\text{NSN Movement}} \times 100 = \text{EFF1}$

2 $\frac{\text{NSN Movement} - \text{TRE12}}{\text{NSN Movement}} \times 100 = \text{EFF2}$

The tracking limit set within system 3 equates to 3 standard deviations. Breaking this tracking limit is generally accepted within distribution as indicative of an out of control situation. The table below is an extract from that at Annex B which shows by DMC the degree of control or level of efficiency achieved within the system. A single break of the limits (EFF2) may be as a result of a cyclical/seasonal surge or may be a trend. Greater than 2 breaks (EFF1) is a more accurate indicator of the level of control being exercised by the use of exponential smoothing. This degree of control is clearly seen as being least effective for those DMC's allocated to technical or engineering spares.

This gave a clear indication of the validity and stability of issues.Within each DMC two sets of results are shown. A full listing is at Annex B.

INVENTORY ANALYSIS

DMC	ROD	RD1	RD2	MLO	ML1	ML2	MLU	MLE	RD	TOTAL	NIL MOV	NSN MOV	TRE 12	TRE 2	EFF 2	EFF 1
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)
CA	326	527	17	197	193	42	194	9	96	1302	299	1003	799	59	23.3%	94.1%
CB	492	790	30	158	213	39	131	5	122	1722	258	1464	1072	69	26.8%	95.3%
CC	47	83	8	28	66	13	15	3	2	245	20	225	170	21	24.4%	90.7%
CD	223	322	8	99	38	17	60	4	54	707	118	589	385	25	34.6%	95.8%
CE	40	71	7	121	194	16	20	111	13	449	144	305	288	23	5.6%	92.5%
CF	306	570	35	94	13	9	82	8	217	1027	307	720	627	44	12.9%	93.9%

Figure 6-1

The recorded achievements are shown at Figure 6.1. The system effi ciency rating tells the manager nothing of the possible understocking, overstocking or failures caused by the forecasting and inventory control accuracy for the total system. Service level by its very for mula relates to items which are being issued. In order therefore to assess the actual efficiency of the operation it was decided that over the 3 year span that has been analysed any item that had not moved would be excluded from the calculations.

To crash the error tracking limit a demand must fall outside 3 σ which is a reasonably generous allowance. The inventory was therefore further categorised into those breaking the error limit once and more than once. (NSN1 and NSN2). Having iden tified those NSN's which continualy exceeded the present limits it was possible to state the expected or actual efficiency of the present system. By using the Domestic Management Code (DMC) it was further possible to identify which DMC's had the highest incidence of failure and theoretically the greatest scope for improvement. The percentage efficiency was taken as being:

$$\frac{\text{No of Failure}}{\text{DMC TOTAL}} \times 100$$

The span of success/failure by NSN is illustrated in the graph below:

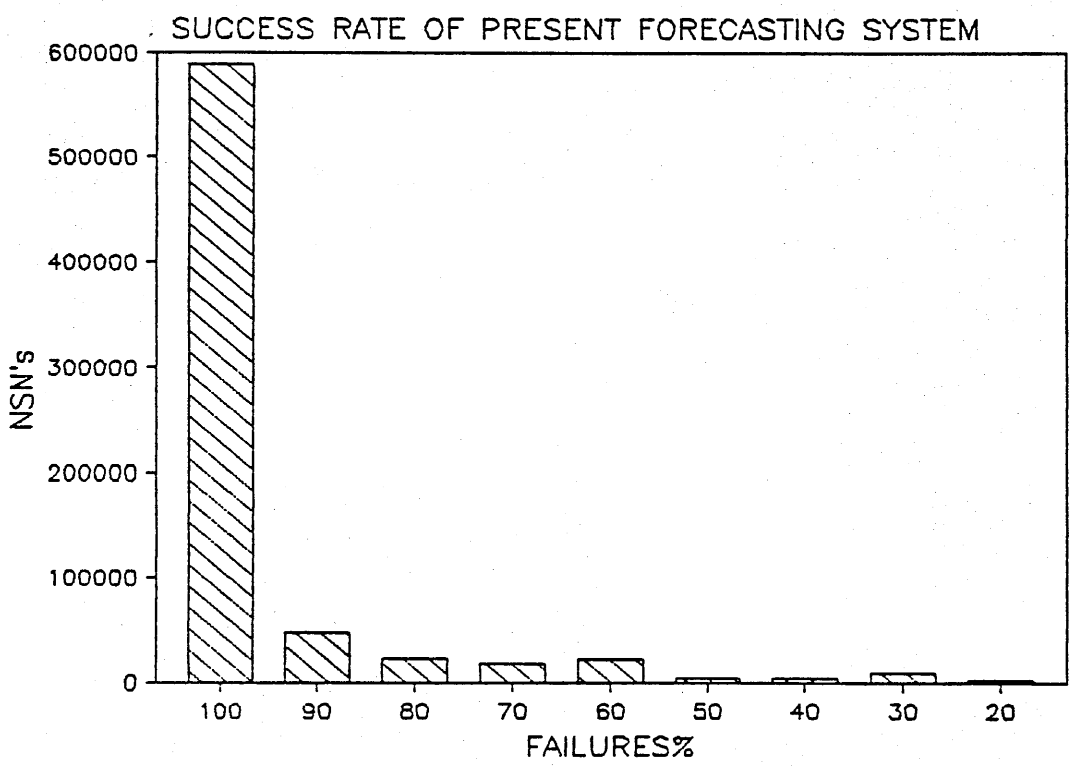


Fig 6.2

By extracting the issue frequency from the data base it was possible to reduce the inventory requiring analysis from 750,000 to 240,000. The usage pattern for the two primary depots was additionally analysed in an attempt to see whether greater analysis was required in the tech or non-tech spares. The analyses show that Donnington had 66.5% of nil moving items and Bicester 34.3% of nil moving whilst the Inventory overall percentage was 63.85%. This type of analysis must however be regarded with some suspicion. The argument against using it is that there is a constant flow between the non-moving and slow moving category. It was further argued by the Provisioners within the (DSM(A) Divisions that some of these items would be critical and experience high usage during conflict. The same provisioners when questioned about their technical knowledge and background were not prepared even with 10 years data and the technical specification for an individual item to declare redundancy or recommend total outscaling. These contradictory arguments represent one of the major differences between the Profit and Maintenance inventories approaches to non-moving spares. Whenever the slow moving item was found in a profit orientated company it was reviewed carefully and removed at the earliest possible date. Within the Support or Maintenance inventory for both the Public and the Private sector the complete stock or part of the stock would be retained until the equipment it supported was phased out of service. In some instances the spare would be sold with the equipment or retained as a possible sales item at a later date. None of the Companies taking part in the study considered that the item should be revalued to include the cost to the company of holding the item or give a return on the capital tied up in the item. All of the companies researched believed that their management effort should be concentrated on the fast movers whilst leaving machines to deal with slow or non moving. One company had perhaps the most straight forward approach to cost reduction for this slow moving area. All slow movers were moved to an old unmanned warehouse and once stored the doors were locked. No stock maintenance or S&R was carried out on this stock. By far the largest element of the RAOC Inventory is tied up in non moving or slow moving stock. If the hypothesis is correct then even this element must be regarded as more than just one inventory. The RAOC supports the REME Base repair programme outlined in Chapter Two and a percen tage of the NSN's will be dependent demand based on known data. They are therefore not non-moving but bought in advance of requirement. They should therefore not be considered in an analysis of slow/non moving stock. Independent demand items within the category will either never be issued or may experience random demand patterns. It is within this area that categorisation of criticality and impact upon operability is necessary. A reduction of inventory held within this category would have the following financial reduction on the capital holdings of the inventory.

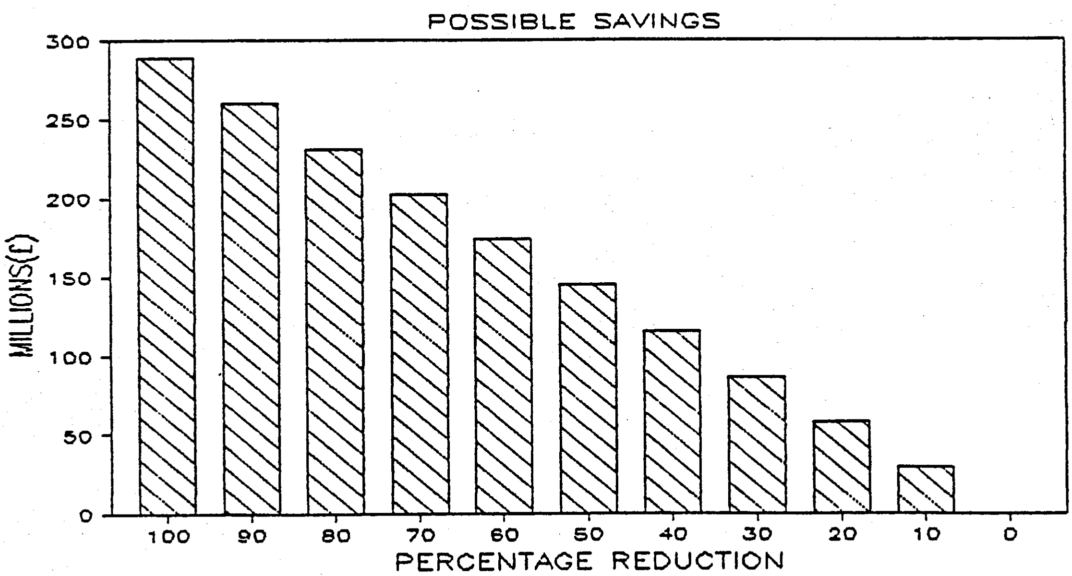


Fig 6.3

The estimated saving is in the order of £2.89 M per percent reduction.

From Fig 6.1 it is apparent that the efficiency of the system is poor. It was decided to investigate this efficiency further. As the RAOC system depends on stock being drawn forward by an overseas depot to support its dependency the withdrawal of a large amount of stock would exceed the normal 3 limits. As it is unlikely for an overseas theatre to draw more than twice in any one year a second analysis on those items which exceeded the 3 limits twice or more was carried out. (System 2 did not differentiate between a customer or a depot demand, System 3 does but the inflationary effect upon the FQD may result in a reversion to System 2 data collection). The results of this second analysis are shown below and reflect a much improved level of efficiency.

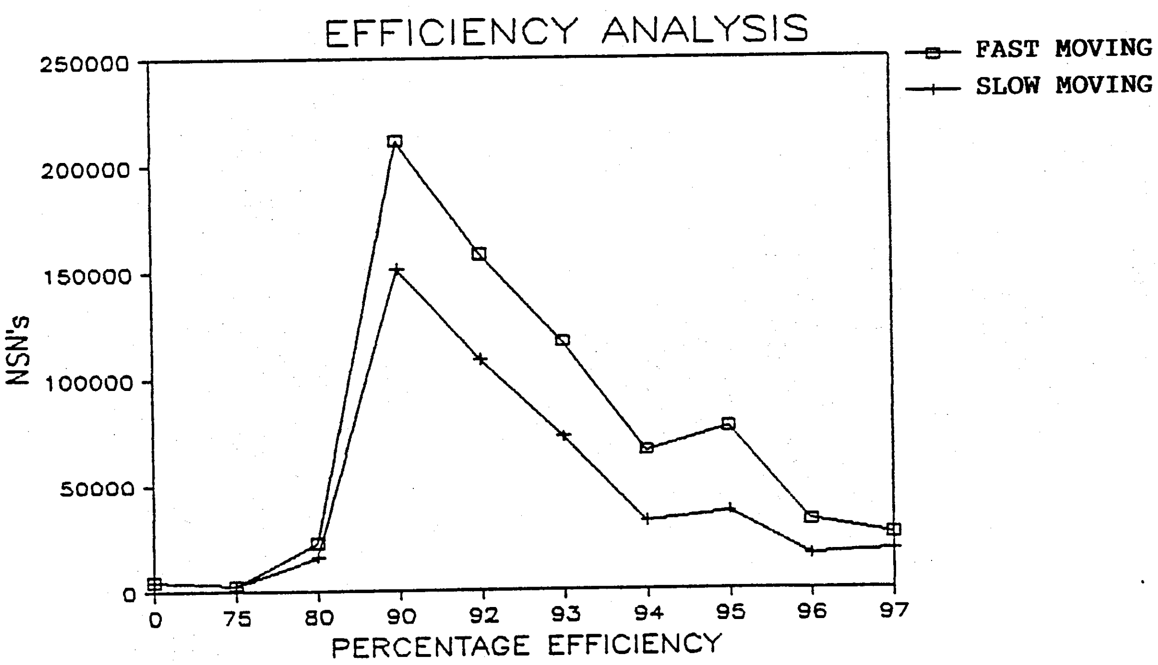


Fig 6.4.

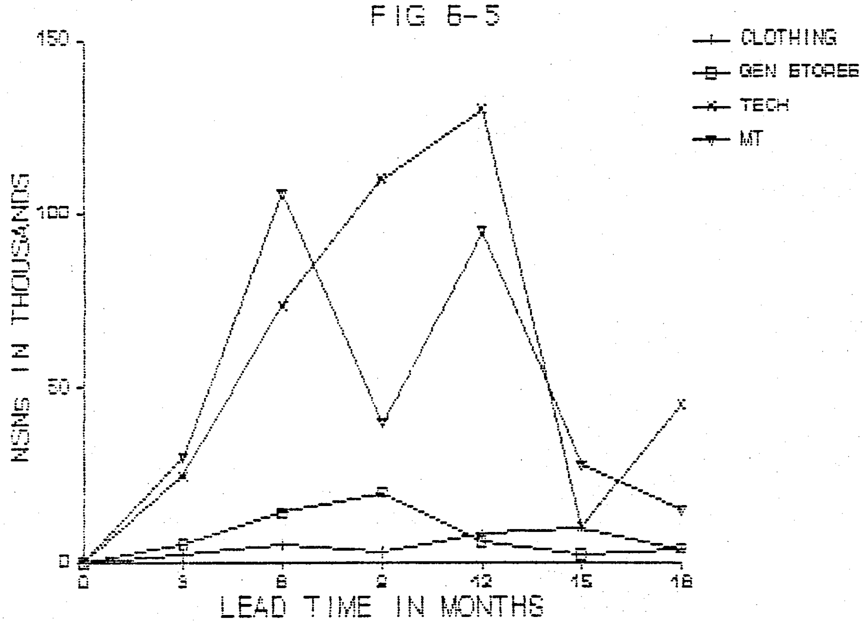
The true level of efficiency of the programmed calculations must however lie somewhere in between the 2 means of Fig 6.2 and Fig 6.4. The secondary depot in BAOR holds an upper limit of stock in the region of 80,000 NSN's whereas the actual live inventory is about 250,000. The current situation is that the efficiency level of the present EOQ/ROL system lies in the region of between 10 and 70% across the complete range but the lower quartile contains the majority of the fast moving items.

6.4.1. Lead Time Analysis (Macro)

The RAOC have been aware that the 'excessive stock holding in comparison with commercial practice' relates in many instances to the long lead times experienced by many part numbers. This was identified most clearly in the Raynor Report conducted in 1976. Recognition of a problem and the means to rectify that problem are not always clear cut. Purchase orders placed by the RAOC have traditionally taken 6 months from raising by the provisioner to receipt by the contractor. This problem has also been identified and the problem addressed by reorganisation within the procurement executive. The diversification of procurement methods has reduced the administrative lead time of many of the more frequently purchased items to months if not weeks and the use of running contracts is well established. This progress is now being reflected in some suppliers (especially B vehicle spares) inability to forecast their own stock levels. The MOD order is of sufficient size to create lumpy demand which their forecasting systems are unable to cope with.(Source of data withheld)

The Supplier Lead Time is therefore increasing in direct proportion to the reduction in MOD internal administrative Lead Time. Regrettably however for slow moving, infrequent orders or military specials the delay is not so much with the procurement but the ability of the contractor to programme short runs, job lots or make to order items. Within the RAOC the lead time is regarded as the elapse of time from raising the requisition until that moment in time when the stock is on the shelf ready for issue. In most cases therefore there are two elements of administration lead time: That during processing of the requisition and that time spent processing the receipt. The graph of figures 6.5 shows an analysis of lead time for the complete inventory showing a mean lead time of 10 months. This graph is however contentious in that with the large number of non-moving items held the old lead times (approx 60% of the inventory) distort the 1988 true lead time. The scenario for war described in Chapter 2 indicates that any future war will have to be fought with off the shelf stocks as there will be insufficient time for industry to gear up. Many of the RAOC items have comparable civilian equivalents and for those high tech areas of military hardware, sales will still be continuing. This was evident in the Falklands war when radio spares and equipment, defence stores, engineering plant and many other items were delivered from trade within 36 hours of a requisition being raised. Lead times for some items will therefore, for a short period until contractor stocks are exhausted, reduce to zero. After the initial delivery further stocks of critical items were manufactured to order with many

FIG 6-5



ANALYSIS OF LEAD TIME IN MONTHS OF RAOC INVENTORY not being received until after hostilities ceased. It is impossible to predict what spares will be available immediately from trade on the transition to war but it is practical to assume that some buffer stocks will become available from trade. It is also likely that the concentration of manufacturers on survival coupled with patriotic workers efforts will contract lead times drastically. If therefore the requisition and administrative lead time is also reduced, as happened during the Falklands campaign, all of those items with lead times of less than 12 months in peace will have their lead times significantly reduced. The hypothesis is based on all of those lead times of 12 months and less being regarded as insignificant.

6.5. Micro Analysis

6.5.1. Introduction. The introduction of System 3 involved all of the DSCS staff in a considerable amount of extra work. At the same time a new ADP system was being introducted by DLSA which additionally created a further workload. The request for two random samples from the complete inventory from an individual carrying out a private study although accepted was allocated a low priority. After a 6 month wait it was decided that an alternative approach to gather the required data would have to be found. Random samples for the Stocktaking and Reconciliation (S&R) cells at both Bicester and Donnington were still being produced. The Inventory S&R is carried out by a 2 year perpetual cyclic stocktake with random samples being produced annually These samples were far in excess of the quantity that could be handled by the study. A complete production run for a stocktake already generated by the computer was subjected to a second random sample. A sample of 300 NSNs was taken fromthe Donnington Inventory and a sample of 100 fromthe Bicester Inventory. Each sample was taken using the DMC categorisation such that from each DMC "1 in n" NSN were selected where n is the ratio of the number of NSNs in the DMC to the number of parts to be selected. A subsequent selection of NSNs was made to increase the number of NSNs in certain DMC to reflect the through put pattern deduced from Figure 6-1. A random sample of 527 NSNs was therefore taken from the two Depots S&R files. Ad hoc PRF were then requested manually from the main computer and the relevant data was loaded onto a micro. In all 36,080 items of data were loaded. At this point in time the DSM(A) OR cell indicated that they had a random sample of 100 which was being used to test the efficiency of system 3. This sample was obtained, Ad hoc PRF's requested and this sample was also loaded onto the micro. To maintain flexibility both DBASE and Supercalc databases were set up. All that data shown at para 6.21 was loaded for each sample. The samples S1, S2 and S3 were tested individually and as a combined sample (S1 + S2 + S3). The samples represented:

S1 Bicester Holdings

S2 Donnington Holdings

S3 Or all inventory sample

S1 + S2 + S3 Combined sample.

Statistical tests were carried out on the samples to ascertain their relationship to the (Macro) population. Whilst the individual samples were representative of their respective population when compared with the MIR data it was clear that the inventory population held at Bicester was not the same as that held at Donnington. S3 and the combined sample gave a true representation of the merged MIR data with regard to LT, Demand, WR, Price and Stock Levels. These disparate results were not unexpected as the inventories held at the 2 locations have widely differing product profiles.

BICESTER	DONNINGTON
Low Tech	High Tech
Bulky	Small
Unique parts	Spare parts
Slow/Medium Volume Throughput	Slow/High Volume Throughput
Small Inventory (60,000)	Large Inventory (660,000)
Durable	Fragile with MTBF
Low Cost	High Cost

This disparity further supported the hypothesis that it was not a homogeneous inventory. For analysis purposes and hypothesis testing, it was therefore decided to retain all four samples.

OUTPUT REASON	REVIEW DAY Phase	REVIEW DAY Today	This Output Date	This Output Time	Production UIN	D of Q	Required	Constrained	Achieved	RIGC	PLN	DMC	NATO Stock Number	
PBUY	3 14	3 14	19 10 89	01 21		EA	95	84	99	BFUA9905	03089	J1	9905 99 125 1555	3F

PMS	Establishment Date	IBT	BUY PERIOD Full	BUY PERIOD Remaining	Item History Fiche Number	Super session	Conditionally Related	Inventory Class n	Proc Method	Package Code	Date of Last Purchase	Item Type	Short Item Name	SERIAL No Outstanding
CCI	01 08 68	NOR			07190 G14	00	N	3	D	A	07 11 88	Z	SIGN	11

BANS Ration	Issues	Dues out			INDICATORS Sales	RAF			CNAC	Procurement Reference Number	Proc Ref Code	SAC	Ledger Heading	SSN
0	0	0	0	1	N	Y	N	N		C9343	C	0000	02K12500	860R007A

QUARTERLY CUMULATIVE DEMAND TOTALS

Qtr	RECURRING Number	RECURRING Quantity	REPLENISHMENT (for SSS) Number	REPLENISHMENT (for SSS) Quantity	NON-RECURRING Number	NON-RECURRING Quantity	Out of Control
1	4	73	0	0	0	0	N
2	2	80	0	0	0	0	N
3	2	15	0	0	0	0	N
4	2	10	0	0	0	0	N
5	0	0	0	0	0	0	N
6	7	249	0	0	0	0	N
7	3	133	1	106	0	0	N
8	2	70	0	0	0	0	N
9	3	47	0	0	0	0	N
10	4	50	0	0	0	0	N
11	1	20	0	0	0	0	N
Current	4	557	0	0	1	500	Y

ASSETS (a) TYPE	STOCK	DUES IN	LIABILITIES (b) TYPE	QUANTITY	(b - a) BALANCE	AMENDED BALANCE
WAR RESERVES	0	0	WAR RESERVES	0	0	
SALES EARMARKS	0	0	SALES EARMARKS	0	0	
OTHER EARMARKS	0	0	OTHER EARMARKS	0	0	
FREE A1	46	0	TISEQ	0		
FREE A2	0	0	TISEQ (Last Buy)	0		
EO (Included if a RE item)			DUES OUT	232	355	
NOMINAL	0		SAFETY STOCK	0		
			LEAD TIME QUANTITY	169		
TOTALS	46	0	TOTALS	401	355	
			Requested Projection Quantity		0	
			Cyclic Buy into Phase			
			EOQ Constrained		486	

DUES IN	
Trade	0
Repair	0
Loan	0
Other	0

Misc Quantities	
Current Unreflected	0
Current Loans Disposal Repair	0
Free EO Stock	0
Type 1 Earmarks	0

BUY RECOMMENDATION Value £	Quantity	Amended
1506	841	

BUY DECISION Value £	Quantity	Date for First Delivery

SOD (Man)	0.00
SOD (SRI)	0.00
FOD	169.02
AQF	169.02
EIQ	177
Man Set	N
SHELF LIFE	

Date of Last Maintenance Issue	LEAD TIME (m) Man sett	Calc'd	RE ORDER LEVEL	Projection Quantity	Date of Nil Free Stock	Economic Order Quantity	PRICE (£)	Value Code
06 10 89	3	6	169	169	19 10 89	486	1.790	8

REASONS FOR CHANGE

ICP DETAIL

DATE 04 09 89

FREE STOCK: 105

FREE D/IN: 0

AMD 20

ANNUAL F/USE

4XAQF VALUE =

£ ~~1210.18~~

ECONOMIC RETENTION Period (yrs)	Quantity
8	5408

DISPOSAL	
Restriction	A
Quantity	0
Value £	0

Approved by:

Date approved:

TXN CODE	NATO STOCK NUMBER	D of Q	SERIAL NUMBER	CALLD QUARTERLY DEMAND MANAGEMENT	RETAIN AS TISEQ	TRANSFER TO SALES	PRF	Proc Meth	Excess Issue Quantity	BASIC PRICE	Value
1 3	4	16 17	18 19 20 21	27 28	34 35	41 42	43	44	50 51	61 62	
LNC	9005991251555	EA	11								

Del Pack	DELIVERY DATE	TOTAL DELIVERY	EARMARK ELEMENT	SALES ELEMENT	War Reserve Element	CONSIGNEE	TOTAL ORDER	Running/Demand Order Contract Number
63 64 65	70 71	77 78	84 85	91 92	98 99	104 105	111 112	123

Del Pack	DELIVERY DATE	TOTAL DELIVERY	EARMARK ELEMENT	SALES ELEMENT	War Reserve Element	CONSIGNEE	CYCLIC BUY	Long Lead Buy	LEAD TIME	PMSI	Establishment Date	SERVICE
124 125 126	131 132	138 139	145 146	152 153	159 160	165	166 167	168 169	170 171	172 173	178	179 180

Del Pack	DELIVERY DATE	TOTAL DELIVERY	EARMARK ELEMENT	SALES ELEMENT	War Reserve Element	CONSIGNEE
181 182 183	188 189	195 196	202 203	209 210	216 217	222

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)
DMC	RD0	RD1	RD2	ML0	ML1	ML2	MLU	MLE	RD	TOTAL	NILMOV	NSNMOV	TRE 12	TRE 2	EFF 2	EFF 1
Z10	1	0	0	37	25	1	61	2	1	64	64	0	26	1	0%	0%
Z13	14	3	0	8	3	0	7	4	17	28	28	0	6	0	0%	0%
Z19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%	0%
Z77	0	0	0	580	0	0	580	0	0	580	580	0	0	0	0%	0%
MLR	0	0	0	789	0	0	789	0	0	789	789	0	0	0	0%	0%
W23	0	0	0	40	0	0	40	0	0	40	40	0	0	0	0%	0%
B4	0	0	0	200	0	0	200	0	0	200	200	0	0	0	0%	0%
SP7	0	0	0	1286	0	0	1286	0	0	1286	1286	0	0	0	0%	0%
ESD	0	1	0	0	0	0	0	0	1	1	1	0	1	0	0%	0%
BSF	67	14	0	0	0	0	0	0	81	81	81	0	14	0	0%	0%
ESN	4	2	0	1	0	0	0	1	6	7	7	0	2	0	0%	0%
16	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0%	0%
SP7	0	0	0	411	0	0	411	0	0	411	411	0	0	0	0%	0%
MCV	0	0	0	786	0	0	786	0	0	786	786	0	0	0	0%	0%
SL	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0%	0%
W12	0	0	0	5	0	0	5	0	0	5	5	0	0	0	100%	100%
ERR	18	72	75	142	56	72	192	0	116	435	308	127	275	147	(116.5%)	(15.7%)
ETR	48	91	57	1	1	1	1	2	176	199	179	20	150	58	(650.0%)	61.3%
7SD	21	21	10	0	3	2	3	0	50	57	53	4	36	12	(800.0%)	66.7%
BJS	312	279	128	130	26	6	138	1	691	881	830	51	439	134	(760.8%)	69.5%
7CE	244	329	80	753	81	14	784	10	396	1501	1190	311	504	94	(62.1%)	69.8%
EVT	0	4	2	0	1	0	0	0	4	7	4	3	7	2	(133.3%)	71.4%
ECE	135	78	25	0	0	0	0	0	233	238	233	5	103	25	0%	75.7%
EBX	451	286	89	5	2	0	4	1	811	833	816	17	377	89	0%	76.4%
ENL	295	51	15	0	0	0	0	0	357	361	357	4	66	15	0%	77.3%
EON	50	65	18	0	0	0	0	0	131	133	131	2	83	18	0%	78.3%
X4	6	14	0	4	8	6	5	2	3	38	10	28	28	6	.0%	78.6%
AWH	15	33	8	3	5	2	7	0	40	66	47	19	48	10	(152.6%)	79.2%
EST	117	91	23	152	31	8	148	0	142	422	290	132	153	31	(15.9%)	79.7%
EDR	293	728	173	216	143	14	323	0	891	1567	1214	353	1058	187	(199.7%)	82.3%
7AF	115	640	28	14	8	3	20	1	606	808	627	181	679	31	(275.1%)	82.9%
Y1	1395	1402	331	941	298	17	899	206	2336	4384	3441	943	2048	348	(117.2%)	83.0%
Z16	154	104	16	478	123	30	446	162	264	905	872	33	273	46	(727.3%)	83.2%
CV	182	437	21	339	259	117	232	22	101	1355	355	1000	834	138	16.6%	83.5%
EFE	1215	1086	230	756	246	31	756	5	1834	3564	2595	969	1593	261	(64.4%)	83.6%
BTR	1259	1864	217	339	153	14	282	67	2061	3846	2410	1436	2248	231	(56.5%)	83.9%
Z90	100	228	45	256	196	34	339	112	328	859	779	80	503	79	(528.8%)	84.3%
Z20	43	36	8	11	19	2	22	10	85	119	117	2	65	10	0%	84.6%
W22	72	9	0	373	13	4	356	15	78	471	449	22	26	4	(18.2%)	84.6%
CET	428	1117	207	424	122	24	413	0	379	2322	792	1530	1470	231	3.9%	84.9%
X1	246	89	21	381	38	1	376	17	344	776	737	39	149	22	(282.1%)	85.2%
3RR	306	932	157	778	366	65	903	0	437	2604	1340	1264	1520	222	(20.3%)	85.4%
7MD	86	350	59	0	1	0	0	0	274	496	274	222	410	59	(84.7%)	85.6%
Z7	582	1312	128	4279	1205	291	3707	1e3	1106	7797	6023	1774	2936	419	(65.5%)	85.7%
U	49	133	27	107	54	4	138	25	147	374	310	64	218	31	(240.6%)	85.8%
GP1	30	144	29	23	38	1	53	9	202	265	264	1	212	30	1%	85.8%
Z8	221	221	35	584	52	9	585	12	330	1122	927	195	317	44	(62.6%)	86.1%
EIH	501	901	142	168	100	17	199	3	1145	1829	1347	482	1160	159	(140.7%)	86.3%
O	2106	1499	223	972	100	24	762	35	1957	4924	2754	2170	1846	247	14.9%	86.6%
Z6	266	387	51	219	229	44	189	156	461	1196	806	390	711	95	(82.3%)	86.6%
V7	132	120	25	784	157	16	702	109	163	1234	974	260	318	41	(22.3%)	87.1%
Z22	711	1554	210	1e4	4500	685	1e4	167	980	20804	15774	5030	6949	895	(38.2%)	87.1%
CJ	101	192	16	137	111	28	35	2	3	585	40	545	347	44	36.3%	87.3%
CC	47	83	8	28	66	13	15	3	2	245	20	225	170	21	24.4%	87.6%

¦7GA	335	59	8	3	0	0	2	1	402	405	405	0	67	8	0%	88.1%
¦7AT	32	77	12	32	27	2	20	15	47	182	82	100	118	14	(18.0%)	88.1%
¦7AL	743	145	20	483	87	11	21	560	896	1489	1477	12	263	31	0%	88.2%
¦ Z5	411	318	29	706	103	26	666	8	395	1593	1069	524	476	55	9.2%	88.4%
¦Z30	4502	8262	1e3	8138	787	108	7954	480	1e4	22865	18692	4173	10225	1176	(145.0%)	88.5%
¦ Z4	2948	3612	426	4075	1970	298	3155	2e3	4795	13329	10039	3290	6306	724	(91.7%)	88.5%
¦ X5	206	391	31	198	163	39	161	17	86	1028	264	764	624	70	18.3%	88.8%
¦ W5	34	42	5	3	6	1	5	5	57	91	67	24	54	6	(125.0%)	88.9%
¦ T7	0	0	0	40	24	3	33	14	0	67	47	20	27	3	(35.0%)	88.9%
¦ W3	1420	2464	306	2046	638	79	2237	41	2680	6953	4958	1995	3487	385	(74.8%)	89.0%
¦BDR	150	338	57	63	90	17	33	0	4	715	37	678	502	74	26.0%	89.1%
¦AHY	5802	6785	755	1890	394	63	1755	105	6314	15689	8174	7515	7997	818	(6.4%)	89.1%
¦1VH	8	33	4	0	0	0	0	0	20	45	20	25	37	4	(48.0%)	89.2%
¦7TR	1123	1439	174	965	350	42	832	118	1861	4093	2811	1282	2005	216	(56.4%)	89.2%
¦Z23	0	3	0	7298	55	7	7115	0	0	7363	7115	248	65	7	73.8%	89.2%
¦ Z3	785	1195	238	1540	2527	210	1663	2e3	1631	6495	5513	982	4170	448	(324.6%)	89.3%
¦7DD	55	24	3	1	1	0	1	0	72	84	73	11	28	3	(154.5%)	89.3%
¦ V4	16	103	14	9	14	0	17	6	128	156	151	5	131	14	1%	89.3%
¦Z14	2418	4895	640	1511	505	24	1656	234	6030	9969	7920	2049	6040	640	(194.8%)	89.4%
¦7BD	2633	5552	490	2963	1475	332	2135	232	3424	13445	5791	7654	7849	822	(2.5%)	89.5%
¦ B3	117	139	14	39	15	4	11	0	27	328	38	290	172	18	40.7%	89.5%
¦EMI	546	1038	113	1322	195	30	1354	12	1057	3244	2423	821	1376	143	(67.6%)	89.6%
¦ J2	124	119	4	340	45	15	290	1	6	647	297	350	183	19	47.7%	89.6%
¦ Y4	925	268	33	356	54	4	327	79	1190	1640	1596	44	359	37	(715.9%)	89.7%
¦ F6	13	26	2	11	9	2	7	0	6	63	13	50	39	4	22.0%	89.7%
¦EAT	353	453	48	1364	391	48	1535	0	402	2657	1937	720	940	96	(30.6%)	89.8%
¦Z32	4237	8094	907	5868	1164	135	5846	532	7952	20405	14330	6075	10300	1042	(69.5%)	89.9%
¦EBR	279	327	35	2	2	2	5	1	599	647	605	42	366	37	(771.4%)	89.9%
¦ X3	8392	1e4	1e3	7538	1732	277	7243	1e3	2e4	31951	24165	7786	16021	1617	(105.8%)	89.9%
¦ M1	112	168	13	166	56	12	137	16	35	527	188	339	249	25	26.5%	90.0%
¦ H1	357	378	21	344	148	37	308	38	76	1285	422	863	584	58	32.3%	90.1%
¦Z17	73	165	42	602	333	12	463	366	160	1227	989	238	552	54	(131.9%)	90.2%
¦Z21	407	286	31	3017	1295	138	2761	628	498	5174	3887	1287	1750	169	(36.0%)	90.3%
¦7SL	1249	2829	230	2533	901	168	2044	1e3	2263	7910	5319	2591	4128	398	(59.3%)	90.4%
¦7RT	161	741	78	55	131	15	45	141	773	1181	959	222	965	93	(334.7%)	90.4%
¦ X2	1717	2866	287	1953	641	87	1946	394	3220	7551	5560	1991	3881	374	(94.9%)	90.4%
¦ V3	164	285	29	156	19	3	160	9	411	656	580	76	336	32	(342.1%)	90.5%
¦Z11	152	413	122	800	1250	53	1387	547	337	2790	2271	519	1838	175	(254.1%)	90.5%
¦ W6	1340	1152	109	1940	552	69	2113	55	1847	5162	4015	1147	1882	178	(64.1%)	90.5%
¦ Y2	3298	4445	455	2555	419	53	2680	65	6121	11225	8866	2359	5372	508	(127.7%)	90.5%
¦3CC	171	291	20	115	35	14	90	1	33	646	124	522	360	34	31.0%	90.6%
¦T13	1556	2262	229	1964	944	104	1350	705	2242	7059	4297	2762	3539	333	(28.1%)	90.6%
¦ERB	377	28	3	8	1	0	9	0	406	417	415	2	32	3	0%	90.6%
¦Z31	2952	5512	591	4700	806	61	4831	331	6892	14622	12054	2568	6970	652	(171.4%)	90.6%
¦ 4	989	2542	261	39	18	3	41	6	2193	3852	2240	1612	2824	264	(75.2%)	90.7%
¦ V5	1217	2885	258	2606	1361	170	1973	1e3	1841	8497	5089	3408	4674	428	(37.1%)	90.8%
¦ CH	200	217	2	229	142	34	128	0	20	824	148	676	395	36	41.6%	90.9%
¦T10	519	1128	95	740	215	39	650	10	776	2736	1436	1300	1477	134	(13.6%)	90.9%
¦7ML	579	1095	118	961	665	57	996	142	916	3475	2054	1421	1935	175	(36.2%)	91.0%
¦W20	164	471	43	269	103	14	267	8	324	1064	599	465	631	57	(35.7%)	91.0%
¦ D1	97	188	18	22	25	3	20	24	73	353	117	236	234	21	.8%	91.0%
¦AAD	587	1997	196	54	54	6	64	7	1431	2894	1502	1392	2253	202	(61.9%)	91.0%
¦T11	72	208	19	34	17	3	19	7	116	353	142	211	247	22	(17.1%)	91.1%
¦Z37	3349	5848	546	4006	1239	141	3992	695	7032	15129	11719	3410	7774	687	(128.0%)	91.2%
¦7RR	496	1304	138	402	173	5	341	37	1122	2518	1500	1018	1620	143	(59.1%)	91.2%
¦ B2	194	356	32	478	109	13	475	46	235	1182	756	426	510	45	(19.7%)	91.2%
¦MT8	262	566	52	48	66	9	27	49	301	1003	377	626	693	61	(10.7%)	91.2%
¦EHM	121	367	17	193	110	29	237	0	162	837	399	438	523	46	(19.4%)	91.2%
¦1TM	20	83	8	0	0	0	0	0	49	111	49	62	91	8	(46.8%)	91.2%
¦7PN	308	529	40	818	209	31	660	13	82	1935	755	1180	809	71	31.4%	91.2%
¦7WG	348	601	57	408	73	7	395	37	663	1494	1095	399	738	64	(85.0%)	91.3%
¦ B6	556	572	56	1005	159	13	1037	64	1034	2361	2135	226	800	69	(254.0%)	91.4%

¦ Z	24	115	10	5	2	1	7	1	90	157	98	59	128	11	(116.9%)	91.4%
¦MT7	721	1530	127	323	137	27	281	41	825	2865	1147	1718	1821	154	(6.0%)	91.5%
¦EGC	169	369	29	72	21	7	82	2	329	667	413	254	426	36	(67.7%)	91.5%
¦W15	139	227	21	171	46	4	162	28	311	608	501	107	298	25	(178.5%)	91.6%
¦RAP	1	0	0	240	7	1	236	0	1	249	237	12	8	1	33.3%	91.7%
¦EHR	137	198	18	237	12	1	211	1	312	603	524	79	229	19	(189.9%)	91.7%
¦BTN	320	747	38	244	574	27	2	544	615	1950	1161	789	1386	65	(75.7%)	91.8%
¦7PK	34	45	0	547	11	5	540	0	14	642	554	88	61	5	30.7%	91.8%
¦Z42	4020	9648	837	7978	1687	170	7910	493	7927	24340	16330	8010	12342	1007	(54.1%)	91.8%
¦ P1	970	1161	102	647	80	8	596	20	1730	2968	2346	622	1351	110	(117.2%)	91.9%
¦BOE	227	648	29	56	69	12	62	50	423	1041	535	506	758	41	(49.8%)	91.9%
¦MTE	821	2002	193	759	328	11	617	251	1878	4114	2746	1368	2534	204	(85.2%)	91.9%
¦ H5	26	34	1	90	58	7	80	1	9	216	90	126	100	8	20.6%	92.0%
¦ F2	6	19	1	9	4	1	7	0	0	40	7	33	25	2	24.2%	92.0%
¦ CE	40	71	7	121	194	16	20	111	13	449	144	305	288	23	5.6%	92.0%
¦7RS	172	414	31	2115	817	75	2184	15	143	3624	2342	1282	1337	106	(4.3%)	92.1%
¦ W7	355	815	64	315	68	12	298	43	638	1629	979	650	959	76	(47.5%)	92.1%
¦W17	4058	5406	429	5052	781	103	4592	384	7150	15829	12126	3703	6719	532	(81.4%)	92.1%
¦7TC	67	235	9	297	465	51	466	10	221	1124	697	427	760	60	(78.0%)	92.1%
¦ENC	590	47	4	1	0	0	1	0	637	642	638	4	51	4	0%	92.2%
¦MT1	4103	8994	725	3420	1243	145	2769	584	5069	18630	8422	10208	11107	870	(8.8%)	92.2%
¦ F3	200	390	30	51	23	5	41	3	134	699	178	521	448	35	14.0%	92.2%
¦ J1	283	358	10	103	67	26	86	1	174	847	261	586	461	36	21.3%	92.2%
¦Z18	52	66	4	2420	242	22	2211	73	41	2806	2325	481	334	26	30.6%	92.2%
¦ H2	154	137	6	66	65	11	51	4	13	439	68	371	219	17	41.0%	92.2%
¦MT3	1066	2218	145	872	357	70	585	149	1223	4728	1957	2771	2790	215	(.7%)	92.3%
¦ARV	36	36	3	0	0	0	0	0	49	75	49	26	39	3	(50.0%)	92.3%
¦ N3	287	729	62	44	65	4	53	10	431	1191	494	697	860	66	(23.4%)	92.3%
¦ Y3	760	1612	121	479	134	24	493	24	888	3130	1405	1725	1891	145	(9.6%)	92.3%
¦ W1	653	813	62	359	80	12	352	45	1117	1979	1514	465	967	74	(108.0%)	92.3%
¦T12	1607	3342	243	1554	894	103	1678	94	2352	7743	4124	3619	4582	346	(26.6%)	92.4%
¦7ZP	134	223	13	706	146	5	780	2	205	1227	987	240	387	18	(61.3%)	92.5%
¦ H8	60	137	9	51	49	6	27	47	79	312	153	159	201	15	(26.4%)	92.5%
¦ B1	378	752	43	92	118	27	56	22	177	1410	255	1155	940	70	18.6%	92.6%
¦ M4	118	111	9	29	14	1	23	3	156	282	182	100	135	10	(35.0%)	92.6%
¦ A1	45	38	2	36	37	4	45	16	5	162	66	96	81	6	15.6%	92.6%
¦W11	83	254	21	14	11	0	7	9	163	383	179	204	286	21	(40.2%)	92.7%
¦ Z1	2645	5207	377	6429	3156	285	6273	2e3	5920	18099	14134	3965	9025	662	(127.6%)	92.7%
¦ Z9	161	293	22	247	99	9	258	14	334	831	606	225	423	31	(88.0%)	92.7%
¦ V6	159	344	29	27	49	2	19	20	271	610	310	300	424	31	(41.3%)	92.7%
¦ W2	2580	3050	238	1383	252	22	1233	232	4418	7525	5883	1642	3562	260	(116.9%)	92.7%
¦ H9	178	338	20	139	85	13	202	12	144	773	358	415	456	33	(9.9%)	92.8%
¦ A4	104	245	8	374	409	43	287	209	112	1183	608	575	705	51	(22.6%)	92.8%
¦EBY	667	592	44	78	25	4	69	0	850	1410	919	491	665	48	(35.4%)	92.8%
¦7FD	782	1823	203	3013	1993	92	3540	120	1302	7906	4962	2944	4111	295	(39.6%)	92.8%
¦W21	20	4	0	125	22	2	112	2	21	173	135	38	28	2	26.3%	92.9%
¦1SC	351	912	60	1014	64	15	1000	1	119	2416	1120	1296	1051	75	18.9%	92.9%
¦ 10	1052	2113	146	61	81	5	30	41	1270	3458	1341	2117	2345	151	(10.8%)	92.9%
¦ CK	157	220	7	129	184	24	63	12	30	721	105	616	435	31	29.4%	92.9%
¦W18	343	772	67	874	220	8	934	109	912	2284	1955	329	1067	75	(224.3%)	93.0%
¦ M3	359	734	49	237	206	22	81	282	683	1607	1046	561	1011	71	(80.2%)	93.0%
¦ CP	306	570	35	94	13	9	82	8	217	1027	307	720	627	44	12.9%	93.0%
¦EAC	225	614	38	423	185	22	399	22	412	1507	833	674	859	60	(27.4%)	93.0%
¦ETX	768	737	99	2836	404	30	2402	3	597	4874	3002	1872	1270	129	32.2%	93.1%
¦ T8	0	0	0	119	190	14	99	96	0	323	195	128	204	14	(59.4%)	93.1%
¦MT9	3804	8307	576	3340	968	107	3108	271	5967	17102	9346	7756	9958	683	(28.4%)	93.1%
¦EXE	250	234	20	125	52	1	136	1	262	682	399	283	307	21	(8.5%)	93.2%
¦7VO	433	976	52	1241	309	41	1133	15	436	3052	1584	1468	1378	93	6.1%	93.3%
¦ N1	1078	1978	139	157	148	14	137	62	1561	3514	1760	1754	2279	153	(29.9%)	93.3%
¦ASC	554	786	70	76	23	4	66	0	340	1513	406	1107	883	74	20.2%	93.3%
¦7RU	1585	2938	185	961	379	52	729	83	653	6100	1465	4635	3554	237	23.3%	93.3%
¦W10	680	913	59	472	181	19	466	62	1079	2324	1607	717	1172	78	(63.5%)	93.3%

¦ CD	223	322	8	99	38	17	60	4	54	707	118	589	385	25	34.6%	93.5%
¦ H6	103	284	16	62	62	8	89	2	140	535	231	304	370	24	(21.7%)	93.5%
¦T14	261	391	20	57	87	13	20	58	53	829	131	698	511	33	26.8%	93.5%
¦ CB	492	790	30	158	213	39	131	5	122	1722	258	1464	1072	69	26.8%	93.6%
¦Z99	1602	2073	129	1373	256	29	1220	81	1492	5462	2793	2669	2487	158	6.8%	93.6%
¦ W8	751	1427	74	1081	186	34	886	146	1206	3553	2238	1315	1721	108	(30.9%)	93.7%
¦7DN	20	55	2	4	5	2	4	0	32	88	36	52	64	4	(23.1%)	93.8%
¦VSM	352	893	60	4	8	0	3	2	516	1317	521	796	961	60	(20.7%)	93.8%
¦ W4	949	1590	104	139	50	5	110	16	851	2837	977	1860	1749	109	6.0%	93.8%
¦ C2	28	64	1	67	12	4	72	0	16	176	88	88	81	5	8.0%	93.8%
¦ KG	699	1563	96	987	68	11	950	47	1332	3424	2329	1095	1738	107	(58.7%)	93.8%
¦ CY	111	154	13	274	442	26	128	236	52	1020	416	604	635	39	(5.1%)	93.9%
¦1MM	38	245	16	1	2	0	1	0	10	302	11	291	263	16	9.6%	93.9%
¦ECS	733	1135	77	910	96	2	828	3	1444	2953	2275	678	1310	79	(93.2%)	94.0%
¦EAB	693	858	52	315	63	7	312	3	1066	1988	1381	607	980	59	(61.4%)	94.0%
¦ CA	326	527	17	197	193	42	194	9	96	1302	299	1003	779	59	22.3%	94.1%
¦EAG	5	12	1	536	10	2	512	0	3	566	515	51	25	3	51.0%	94.1%
¦CVT	1171	1636	120	600	286	30	525	32	718	3843	1275	2568	2072	150	19.3%	94.2%
¦3LD	386	785	39	51	55	13	56	11	201	1329	268	1061	892	52	15.9%	94.2%
¦7PW	1529	4331	230	2380	535	63	2217	19	2662	9068	4898	4170	5159	293	(23.7%)	94.3%
¦ G1	3539	6515	198	5481	6020	554	5711	338	1245	22307	7294	15013	13287	752	11.5%	94.3%
¦ORD	5588	4978	297	326	57	4	331	6	7039	11250	7376	3874	5336	301	(37.7%)	94.4%
¦ CN	110	129	3	138	122	12	138	20	22	514	180	334	266	15	20.4%	94.4%
¦MT2	154	329	19	498	187	11	362	73	146	1198	581	617	546	30	11.5%	94.5%
¦ KC	78	110	9	55	45	0	40	8	40	297	88	209	164	9	21.5%	94.5%
¦7EA	42	54	4	483	353	20	507	0	1	956	508	448	431	24	3.8%	94.6%
¦ENV	246	515	28	9	6	1	9	3	526	805	538	267	550	29	(106.0%)	94.7%
¦EBP	33	18	1	2	0	0	2	0	40	54	42	12	19	1	(58.3%)	94.7%
¦MT4	3610	8303	369	3961	1693	182	4181	138	4879	18118	9198	8920	10547	551	(18.2%)	94.8%
¦EMG	394	561	30	630	218	11	577	3	553	1844	1133	711	820	41	(15.3%)	95.0%
¦7SA	82	60	6	166	1	0	145	0	49	315	194	121	67	6	44.6%	95.0%
¦MSE	20	34	2	255	257	13	360	2	20	581	382	199	306	15	(53.8%)	95.1%
¦ H4	247	255	10	170	75	7	148	2	32	764	182	582	347	17	40.4%	95.1%
¦MT6	164	320	8	84	69	12	81	19	81	657	181	476	409	20	14.1%	95.1%
¦ C1	408	655	30	167	48	6	180	6	286	1314	472	842	739	36	12.2%	95.1%
¦ F1	1885	2573	95	357	378	53	208	61	473	5341	742	4599	3099	148	32.6%	95.2%
¦Z29	26	109	4	41	32	3	55	7	124	215	186	29	148	7	(410.3%)	95.3%
¦7AH	435	1333	62	73	39	5	56	3	629	1947	688	1259	1439	67	(14.3%)	95.3%
¦ETW	48	43	0	134	39	4	67	0	73	268	140	128	86	4	32.8%	95.3%
¦ECP	1218	2167	100	1031	170	11	1022	42	2797	4697	3861	836	2448	111	(192.8%)	95.5%
¦7TY	411	1143	29	222	295	38	44	431	1004	2138	1479	659	1505	67	(128.4%)	95.5%
¦ T9	0	0	0	23	43	2	19	30	0	68	49	19	45	2	(136.8%)	95.6%
¦ACR	1282	2475	113	229	88	6	182	16	1123	4193	1321	2872	2682	119	6.6%	95.6%
¦ CP	109	271	13	972	1395	64	355	613	42	2824	1010	1814	1743	77	3.9%	95.6%
¦EMB	471	125	8	720	56	4	672	0	436	1384	1108	276	193	12	30.1%	95.7%
¦T15	305	960	40	236	37	4	220	3	880	1582	1103	479	1041	44	(117.3%)	95.8%
¦EPR	271	454	15	100	51	7	155	1	704	898	860	38	527	22	0%	95.8%
¦7CY	295	465	20	776	56	2	740	9	405	1614	1154	460	543	22	(18.0%)	95.9%
¦7LD	925	1829	70	244	116	11	255	35	2221	3195	2511	684	2026	81	(196.2%)	96.0%
¦EBH	70	284	13	31	55	1	61	2	239	454	302	152	353	14	(132.2%)	96.0%
¦EDT	195	439	19	181	32	0	159	20	413	866	592	274	490	19	(78.8%)	96.1%
¦ Z2	464	739	28	211	36	3	206	13	865	1481	1084	397	806	31	(103.0%)	96.2%
¦ E3	158	222	5	64	30	5	48	14	54	484	116	368	262	10	28.8%	96.2%
¦AUS	55	27	1	2	0	0	2	0	79	85	81	4	28	1	(600.0%)	96.4%
¦CVW	301	548	15	169	97	14	142	11	167	1144	320	824	674	29	18.2%	96.5%
¦ G2	470	565	17	153	280	13	270	23	101	1498	394	1104	875	30	20.7%	96.6%
¦ M2	558	1767	59	16	42	3	22	30	2367	2445	2419	26	1871	62	1%	96.7%
¦ W9	162	56	2	5	3	0	8	0	210	228	218	10	61	2	(510.0%)	96.7%
¦ 13	580	550	16	33	3	0	27	0	651	1182	678	504	569	16	(12.9%)	96.8%
¦ CM	57	80	2	83	84	3	25	6	6	309	37	272	169	5	37.9%	97.0%
¦ 12	86	175	7	11	10	1	1	2	7	290	10	280	193	8	31.1%	97.1%
¦7AN	375	1002	26	104	338	13	243	153	1073	1858	1469	389	1379	39	(254.5%)	97.2%

¦7WA	7	34	1	4	3	0	6	0	26	49	32	17	38	1	(123.5%)	97.4%
¦ KA	13	28	1	74	10	0	50	0	3	126	53	73	39	1	46.6%	97.4%
¦ A2	11	33	1	139	56	1	125	5	13	241	143	98	91	2	7.1%	97.8%
¦3JG	170	190	2	16	14	1	11	0	22	393	33	360	207	3	42.5%	98.6%
¦7BC	76	230	3	58	215	3	186	9	114	585	309	276	451	6	(63.4%)	98.7%
¦EDL	20	109	1	9	22	0	24	0	53	161	77	84	132	1	(57.1%)	99.2%
¦ A3	59	89	0	67	61	1	42	10	16	277	68	209	151	1	27.8%	99.3%
¦GWR	0	0	0	263	26	1	127	0	0	290	127	163	27	1	83.4%	99.4%
¦WPG	59	158	1	42	75	0	48	7	69	335	124	211	234	1	(10.9%)	99.5%
¦DDU	0	1	0	0	0	0	0	0	1	1	1	0	1	0	0%	100.0%
¦1LD	1	32	0	0	0	0	0	0	30	33	30	3	32	0	(966.7%)	100.0%
¦ 15	13	12	0	37	11	0	44	3	23	73	70	3	23	0	(666.7%)	100.0%
¦BUD	4	8	0	0	1	0	0	0	8	13	8	5	9	0	(80.0%)	100.0%
¦1NM	3	16	0	0	0	0	0	0	7	19	7	12	16	0	(33.3%)	100.0%
¦1SB	1	11	0	0	0	0	0	0	3	12	3	9	11	0	(22.2%)	100.0%
¦P99	2	2	0	30	3	0	30	0	2	37	32	5	5	0	.0%	100.0%
¦AAE	2	7	0	0	0	0	0	0	2	9	2	7	7	0	.0%	100.0%
¦BRC	13	41	0	0	0	0	0	0	0	54	0	54	41	0	24.1%	100.0%
¦ H7	1	0	0	2	1	0	2	0	0	4	2	2	1	0	50.0%	100.0%
¦AAT	3	2	0	0	0	0	0	0	1	5	1	4	2	0	50.0%	100.0%
¦MLR	0	0	0	2523	1	0	2521	1	0	2524	2522	2	1	0	50.0%	100.0%
¦ELC	1	0	0	524	20	0	470	0	0	545	470	75	20	0	73.3%	100.0%
¦JAV	2	2	0	754	3	0	736	0	2	761	738	23	5	0	78.3%	100.0%
¦Z88	0	3	0	2120	4	0	2085	2	0	2127	2087	40	7	0	82.5%	100.0%

CHAPTER 7. HYPOTHESIS TESTING

7.1 Classification. The research to the thesis, especially that with commercial organisations and the Bundeswehr, has indicated that the present tried and tested methods of controlling inventory have prevented its subdivision. The hypothesis advocates that there is, within large inventories, no such thing as 'an inventory' but rather that there are many sub inventories. These suffer from differing constraints and are therefore impossible to control economically using present methods. The control of inventory in all of the companies who took part concentrated on the proper and correct identification of the item by using a part number. This part number was seldom used for any other purpose but represented a unique number under which data could be retrieved, added to or manipulated. The number represented therefore an identification tag. It has been argued in Chapter 5 that this is insufficient and that a greater degree of classification, allied perhaps to the part number, would enable better control and cost parameters to be set. Classification is not easy, if it were it would already have been achieved and marketed. In its simplest form and crudest the ABC analysis represents the present threshold reached. For an inventory of a few thousand item heading this is sufficient, for large inventories it tends to be impractical and time consuming.

The main arguments against classification are based on who is knowledgeable enough to make the initial classification. Yet data of various technical aspects of each part is normally held already on file. It is perhaps possible therefore that the initial classification should be made on initial stocking or for the current inventory automatically, therefore allowing all to blame the machine. The classification process outlined in this Chapter has been based on that of the RAOC. Not because theirs was the easiest to do but because data and advice on item headings was only a phone call away.

7.2. Initial Classification. The most serious problem, identified in Chapters 4 and 5 is the difference between significant and insignificant spares related to an operational/priority situation. It was decided that as an initial step broad categories as opposed to individual item headings should be considered. The most obvious approach was the Domestic Management Code where, theoretically, like items are grouped. This however proved to be a false approach as the grouping is related to the economic factors and the workload capacity of a provision cell within DSM(A). The only alternative was to go back one stage to the NATO stock number. Composed of 13 digits this number allows the following information to be deduced:

00 - 00 - 00 - 000 - 0000

Country of origin

Unique item identifier

Group

Class division within Group

FSC Breakdown

Figure 7-1

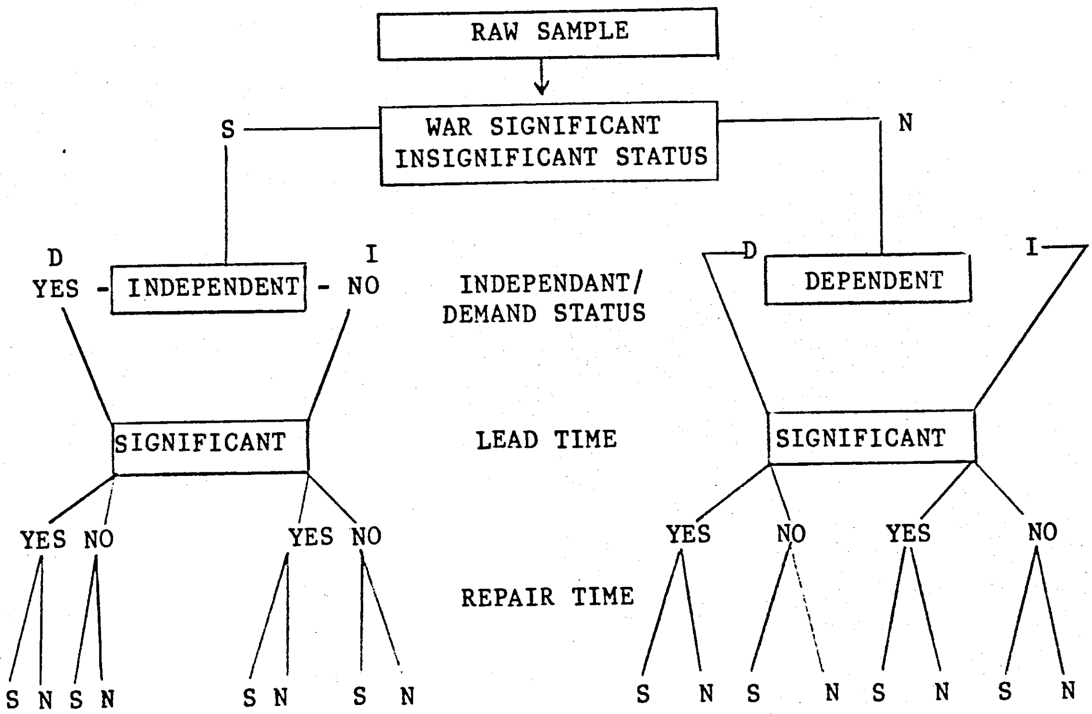
From the first four digits the following type of information is available:

5910 Capacitors

Includes: Interference filter Capacitors; Capacitor mounting hardward.

Excludes: Semi conductor Devices and Associated hardware.

As an alternative approach therefore an additional database was set up which allocated a significant/non significant element purely on the group class division FSC code. Some of the decisions were fairly simple. For example all weapon, A vehicle or combat communication spares and assemblies were classed as significant on the basis that they were military only items. Such things as nuts, bolts, timber steel pipes etc were classed as insignificant. Within both classifications there will probably be items which are incorrectly classified and part of the testing process was to identify whether this was important. Using the hypothesis the following steps were carried out:



Basic Classification Model

Figure 7.2

Whilst the hypothesis argues that it is unnecessary to classify insignificant item headings it was necessary to validate this reasoning and therefore all tests were carried out on significant and non significant items headings. Independant (I), Dependant (D), Repair Time Significant (S) and repair time insignificant (N) were also drawn from the FSC grouping. Lead time significant (S) and lead time insignificant were drawn from the LTC and significant (S), in this test, was taken as any LT in excess of 12 months. This test was accomplished by setting up within DBASE an FSCLOOK file which compared the first four digits of each NSN and then allocated codes. An additional programme checked the LTC and allocated the lead time significance code. The resulting file structure is shown below:

STRUCTURE FOR FILE: A:TEST .DBF
NUMBER OF RECORDS: 00097
DATE OF LAST UPDATE: 10/09/87
PRIMARY USE DATABASE

FLD	NAME	TYPE	WIDTH	DEC
001	NSN	C	016	
002	DMC	C	009	
003	ITEM	C	009	
004	CLASS	C	002	
005	FSC	C	004	
006	ABC	C	002	
007	NS	C	001	
008	ID	C	001	
009	LT	C	001	
010	RT	C	001	
011	WMR	C	001	
012	P1	N	007	
013	P2	N	007	
014	P3	N	007	
015	P4	N	007	
016	P5	N	007	
017	P6	N	007	
018	P7	N	007	
019	P8	N	007	
020	P9	N	007	
021	P10	N	007	
022	P11	N	007	
023	Var	N	007	
024	CONTR	C	001	
025	WRS	N	007	
026	FOD	N	008	
027	LTM	N	003	
028	LTC	N	003	
029	PRICE	N	009	003
030	STOCK	N	007	
031	USAGE	N	008	
032	COST	N	014	
**	TOTAL **		00192	

Each sample was then sorted on NS, ID, LT and RT. This sorting of the base smaples was an attempt to identify patterns within the inventory to ascertain as to whether naturally homogeneous groups could be found. The results are shown in paragraphs 7.2.1.1 to 7.2.1.4.

7.2.1 Tests for Homogeneity.

The consolidated final results are graphically displayed with each sample.

7.2.1.1. Sample 1. The primary Depot 1 sample represented by the two figures below had a predominant quanity of Non significant stock with only 35% of stock regarded as significant. The three majority groups highlighted in the test results are:

a. NINN 42%.

b. NDNS 15%

c. SDNS 19%

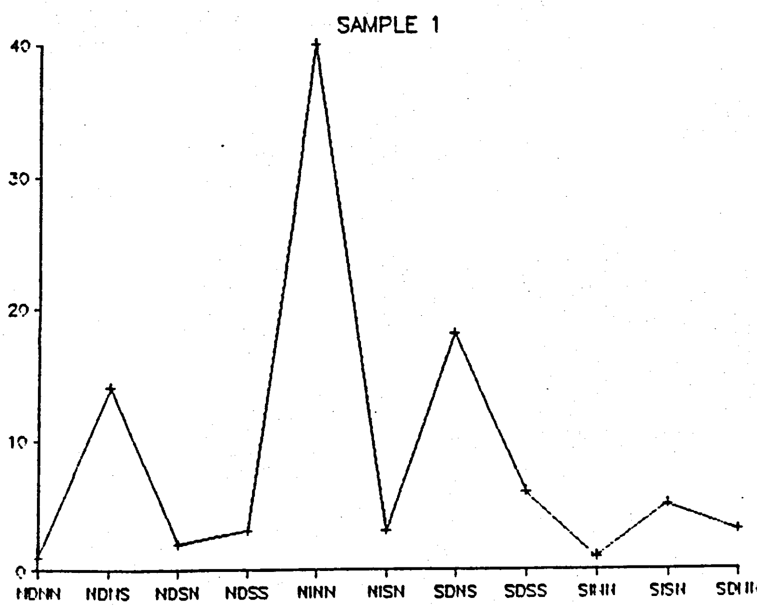


Figure 7-3

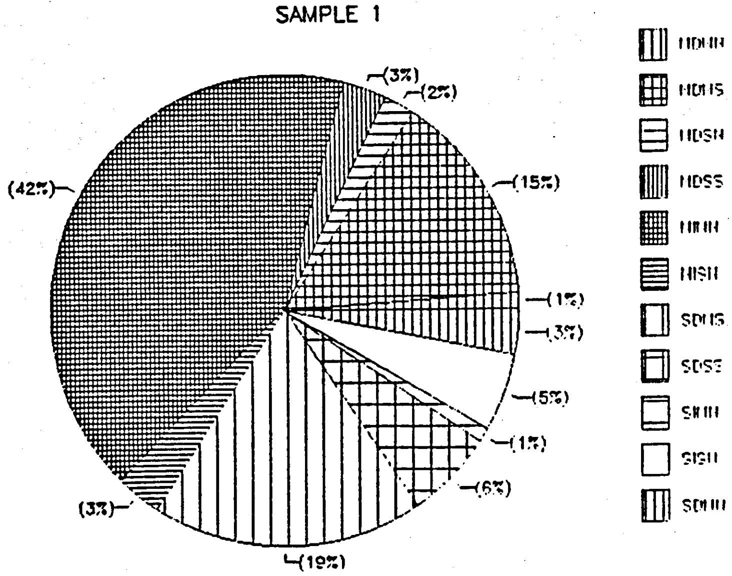


Figure 7-4

7.2.1.2. Sample 2. This primary Depot 1 sample having been drawn from that element of the inventory regarded as technical and composed of those spares most needed in war was expected to produce a majority of significant stock. The results were not quite as expected and gave the first indication that supposition and fact were not in harmony. Again there were majority groups:

a. SDNS 31%.

b. SDSS 17%.

c. NDNS 35%.

d. NISN 7%.

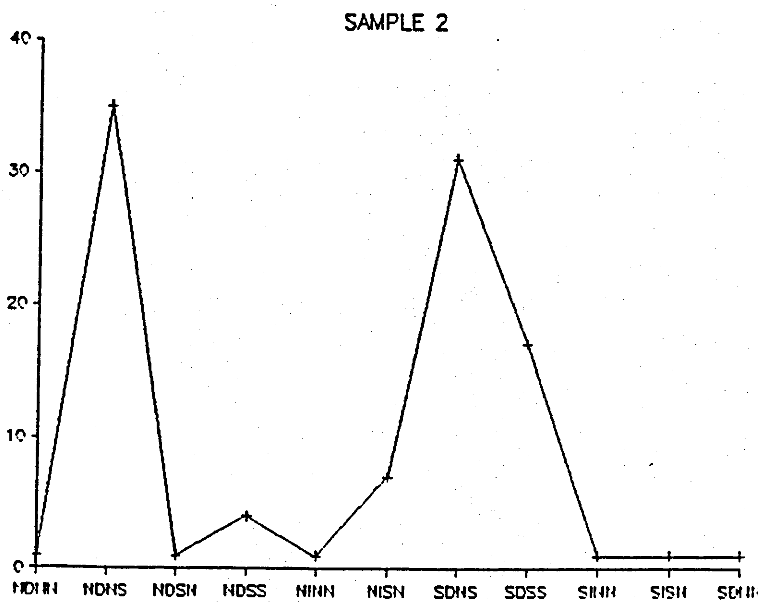


Figure 7-5

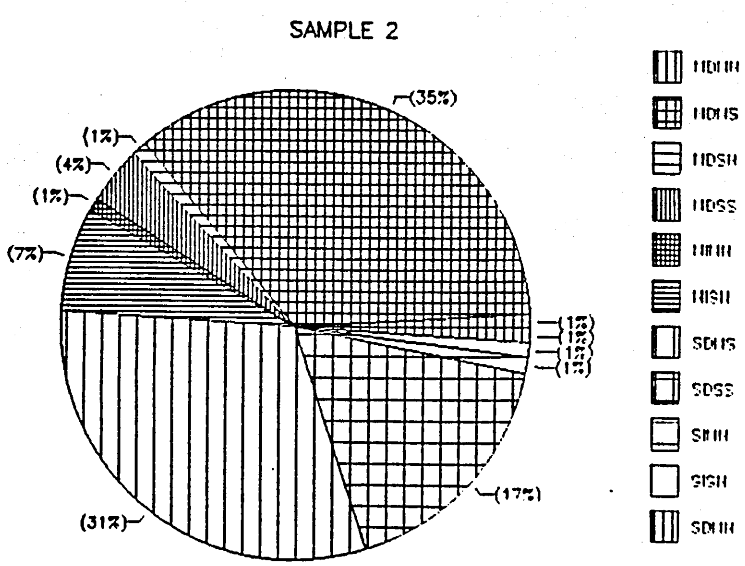


Figure 7-6

7.1.3. Sample 3. This sample having been drawn from across the total inventory in both depots reflected the weighting of both Sample 1 and Sample 2 and produced 6 groups:

a. NINN 35%.

b. NISN 14%.

c. NDNS 11%.

d. SDSS 15%.

e. SDNS 9%.

f. SINN 8%.

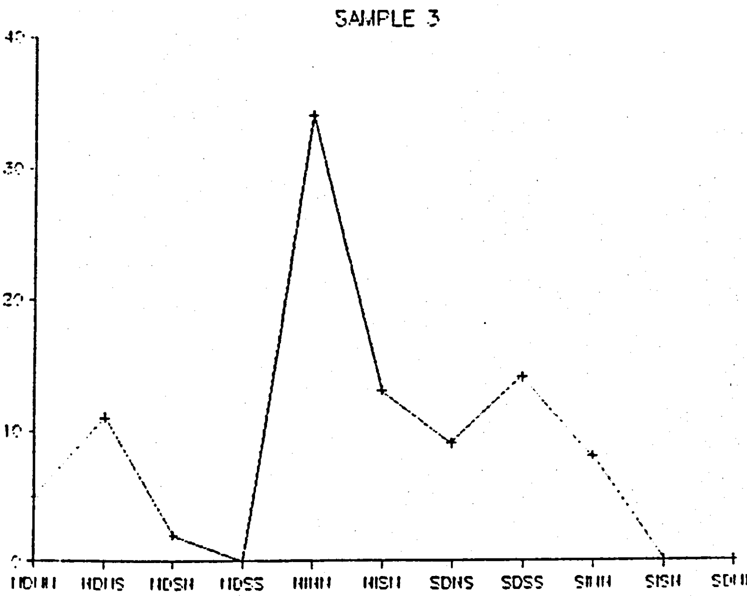


Figure 7-7

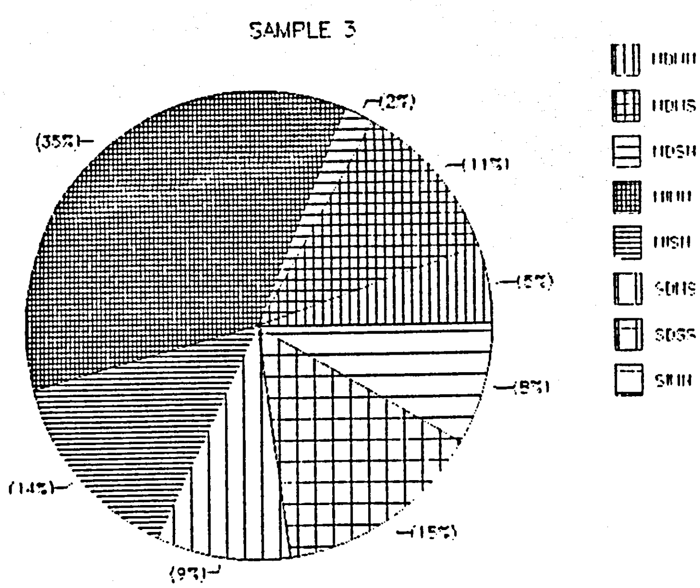


Figure 7-8

7.2.1.4. Combined Sample. The test results have been aggregated to show the split by classification within the inventory. It should be noted that the SINN group reflected only 3%. The main groups were:

a. NINN 26%.

b. SDNS 20%.

c. NDNS 21%.

d. SDSS 13%.

e. NISN 8%.

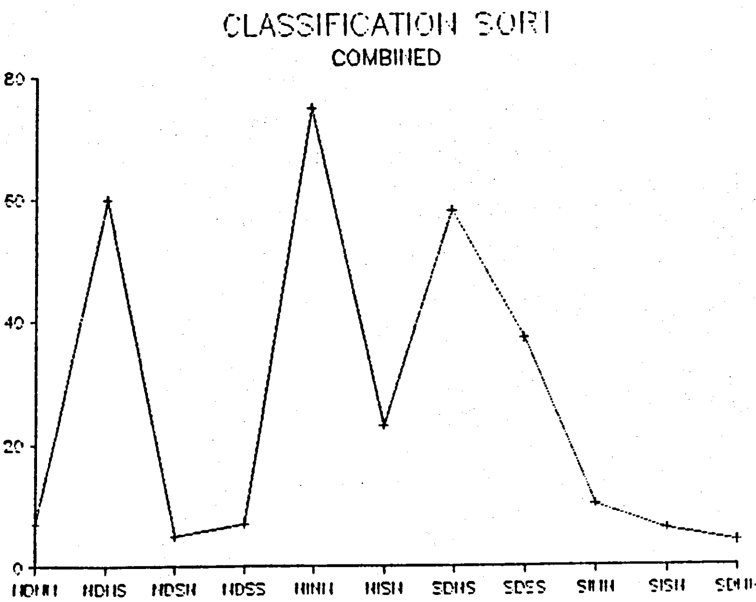


Figure 7-9

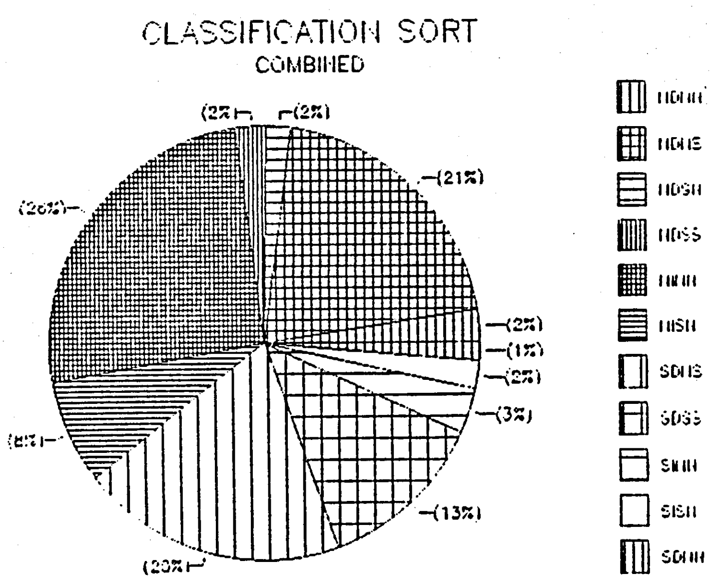


Figure 7-10

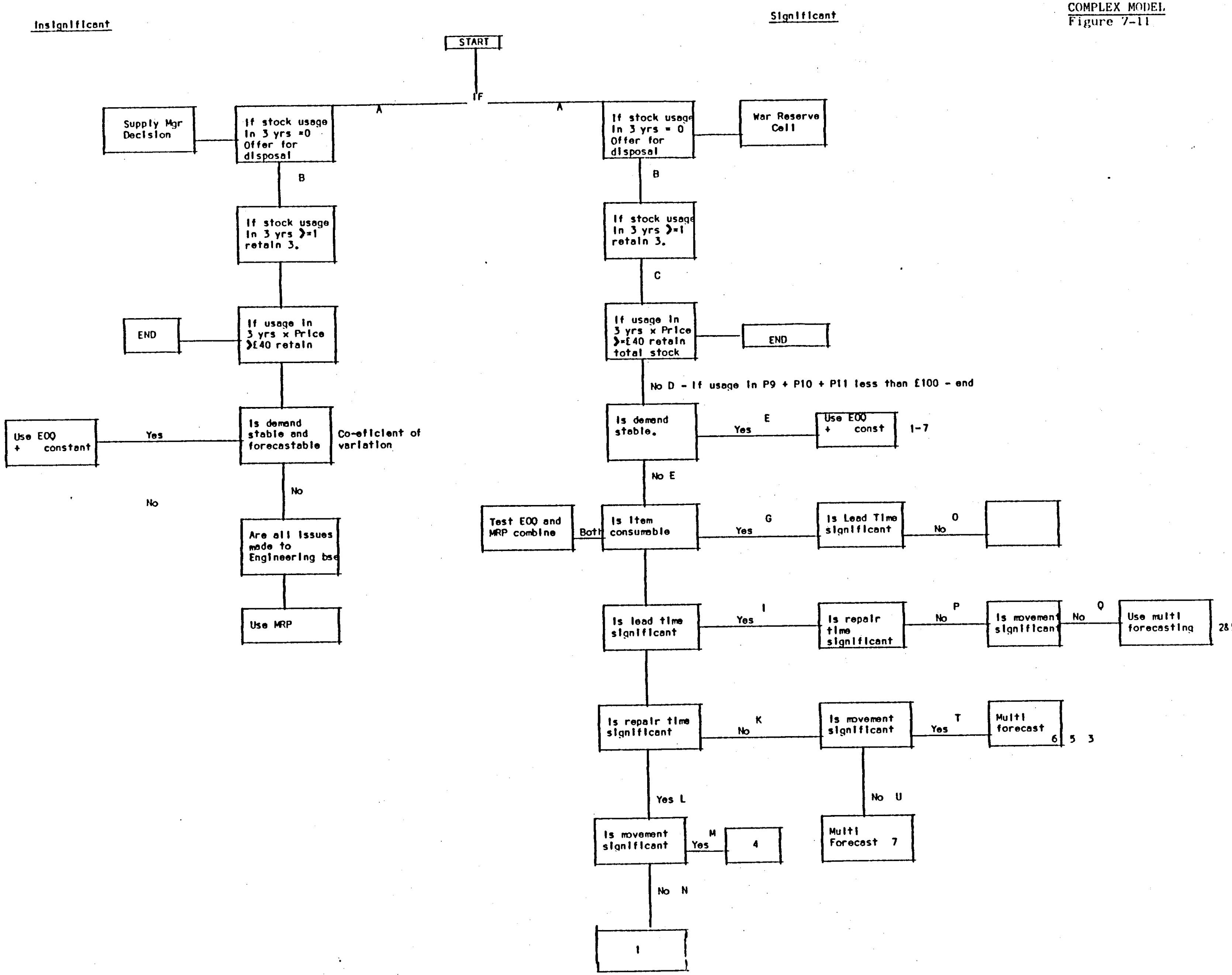
7.2.1.5. Conclusions. If a simple homogeneous group existed the hypothesis would be false whereas if two or three groups were homogeneous the hypothesis may be correct. An examination of the results clearly shows that not only was there no clear homogeneity within individual samples but even when combined there was no improvement. Cluster groups of homogeneous items only appeared when the combined sample was sorted again on usage. It was then fairly evident that an ABC pattern appeared within each homogeneous group. Not only were there several inventories contained within the single inventory but each individual inventory at this first experiment would appear to conform to a Pareto type analysis. Each group contains its fast, slow and erratic usage/moving items but each group is dependent on a different set of constraints and variables. The previous research carried out by statisticians on the RAOC inventory would automatically have failed as although fast, medium and slow moving items have had different systems tried upon them there has never been any attempt to identify the sub groups within these by their dependence/ applicability.

In order to try and produce a simpler method of sorting into homogeneous groups alternative sort methods were attempted. The samples were sorted using the primal variables of FQD minus Mean, Price, Usage Patterns, stock cover, EOQ, FQD and co-efficient of variation. None of these produced a usable sort and even when a selection of these were used as a sort sequence no meaningful sort was produced. It was therefore decided to discontinue the search for a simpler alternative and continue with the classification sort based on FSC.

7.3. Development of Model. Having added what were believed to be the significant variables to the data, such that each item could be manipulated by a complex model the first model was developed and was based on a cascade concept in that individual items or groups would drop out as each major variable was reached. This is diagrammatically represented at Figure 7-11. The objective of the model was two fold in that it should produce those groupings identified in the hypothesis whilst remaining as simple as possible, both to understand and implement. Complex equations and calculations have as far as possible been avoided. It was clearly argued in Chapter 4 that complexity does not necessarily lead to efficiency. The goal was, and remains, an increase in efficiency. This first model paid no attention to priority of variables as these were changed during simulation to identify the variable priority impact.

Sample 1 Simulation 1. The first sample contained 97 item headings drawn from the low tech element of the inventory stored in Primary Depot 1. At the first pass 34 items were identified as significant List 1. At the second pass 11 items were removed as they had a zero usage pattern over 3 years. On the third pass those items with only 1

COMPLEX MODEL
Figure 7-11



issue in 3 years (Total 4) left a sample balance of 19. Assuming a Co variable of £40, removed 1 further element leaving a balance of 18. A co-efficient of variation not exceeding 1 was regarded as being forecastable using EOQ and exponential smoothing and 11 items fell into this category. Of the 7 remaining all fell into the A or B category of the ABC analysis, 5 were dependent based and 2 were independent. The results are shown below:

Extrapolation Sample 1

Results		Sample Balance	Population Equivalent
Total	97	97	58,200
Insignificant	63		37,800
Significant	33	33	19,800
Zero Usage	10	23	6,000
Issues > 1	4	19	2,400
Cost > £40	1	18	600
Stable	8	10	6,000
Unstable	10	0	
Subgroups	4		

SDNS = 4 SISN = 4 SDSS = 1 SINS = 1

Sample 2 Simulation. The second sample contained 98 item headings drawn from the high tech element of the inventory stored in Primary Depot 2. At the first pass 50 items were identified as significant. At the second pass 13 items were removed as they had a zero usage pattern over 3 years. A usage pattern of < 1 removed a further 4 items and a Co variable of £40 a further 5.The co-efficient variable of 1 removed an additional 8 leaving a final balance of 20. These fell into 2 distinct groups and the results are shown below:

Extrapolation Sample 2

Results		Sample Balance	Population Equivalent
Total	98	98	666,400
Insignificant	48		355,200
Significant	50	50	370,000
Zero Usage	13	37	96,200
Issues > 1	4	33	29,600
Cost > £40	5	28	37,000
Stable	8	20	59,200
Unstable	20	0	148,000
Subgroups	2		

SDSS = 9 SDNS = 11

Sample 3 Simulation. The third sample contained 100 item headings drawn from the complete inventory. At the first pass 32 items were found to be significant. The second pass of the model removed 13 and the third pass a further 3. Only 1 item was removed with a Co of £40 but 14 were found to be forecastable using EOQ and exponential smoothing leaving a sample balance of 1. The results are shown below:

Extrapolation Sample 3

Results		Sample Balance	Population Equivalent
Total	100	100	740,000
Insignificant	68		503,200
Significant	32	32	236,800
Zero Usage	13	19	96,200
Issues > 1	3	16	22,200
Cost > £40	1	15	7,400
Stable	14	1	103,600
Unstable	1	0	7,400
Subgroups	1		

SDNS = 1

<u>7.3.1. Extension of Model.</u> The results of the model validated the hypothesis that individual homogeneous groups existed within inventory. Whilst this academic research appeared to justify the increased control value of a classification process it was decided that this was insufficient. A further study was therefore carried out into a single family of equipments for which spares are held. The armoured vehicle spares range numbering some 100,000 automotive spares was chosen as this range of spares contained both high and low tech spares. The research entailed some 6 weeks of data collection and analysis. The methodology was:

a. Review of present system.

b. Effects of alternative classification:

The areas which were monitored to assess the implications of reclassifying were:

(1) Efficiency.

(2) Control.

(3) Resource input.

(4) Service Level.

(5) Capital input.

(6) Inter relation of Players.

(7) Expectation of Customers

(8) Stock Levels.

Instead of purely simulating the impact on inventory the complete distribution flow was dissected and data collected at each point. The breakdown of the flow indicated the reliance on each element of the flow of the passage of detailed information. Failure to communicate this information invariably resulted in stockout or resource overload. The analysis revealed that the present system fails to recognise that each part of the flow, bar one is a customer and a supplier. This failing in the compounding of errors resulting in a total control failure. The system is displayed below:

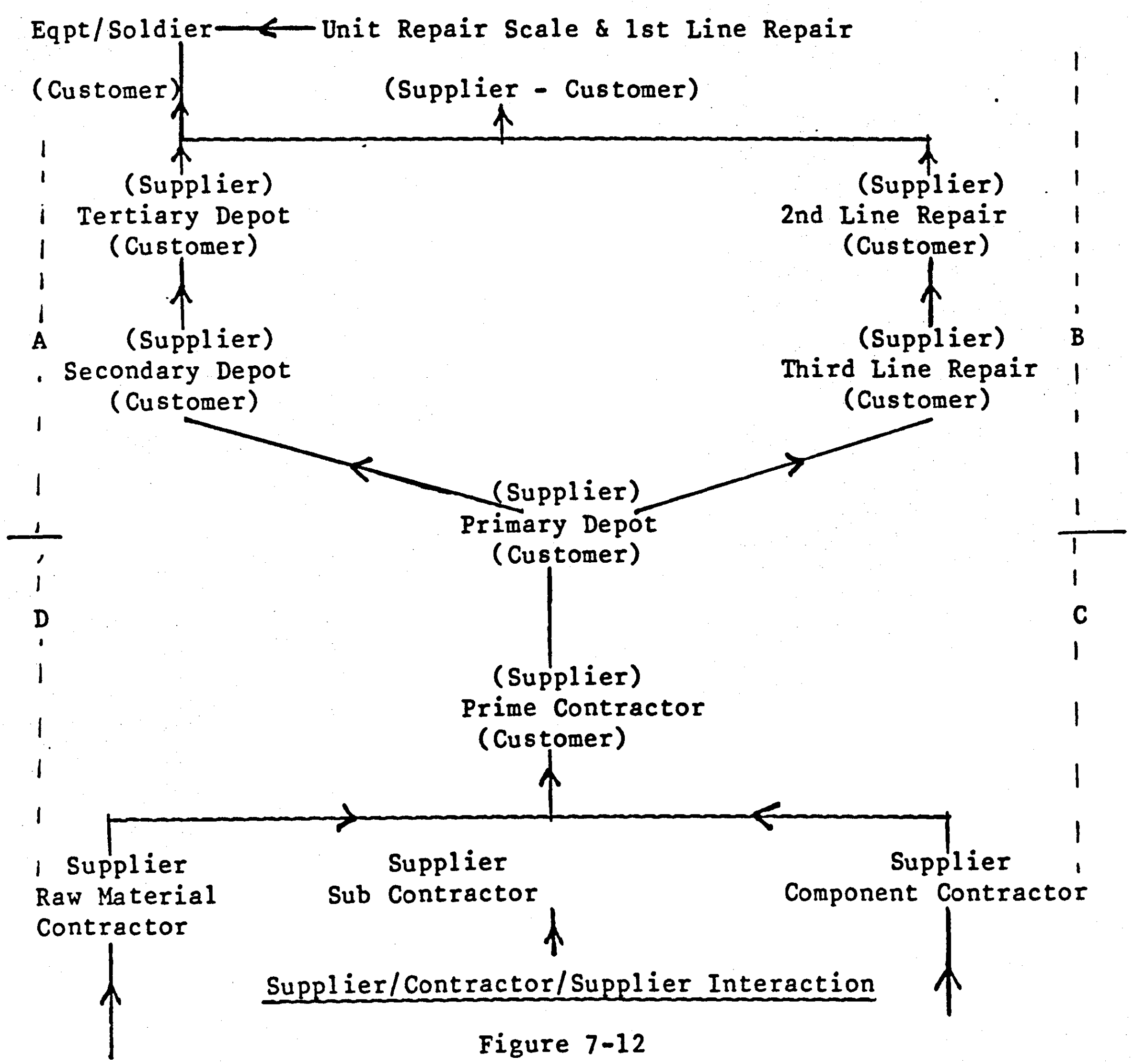


Figure 7-12

Analysis of the demand patterns and requisitions (demands on the Prime contractor) showed that under the present system all demands were treated as random but that:

a. A and D represented mainly random demands (independent).

b. B and C represented mainly predictable demands (dependent but with a significant proportion of random (dependent) and a quantity of demands of both random and predictable (independent and dependent).

On first analysis this represented a simple control problem and an increase in service level would have been achieved by introducing an MRP system for the B and C flow. Further analysis showed however that offtake could move from random to predictable based on changes in repair and usage policy (including modification) by the customers in A and B. This migration of parts from random to predictable and vice-versa cannot be adequately catered for with either an ROL or MRP system. Although a significant improvement in Service level would be achieved by changing Supply Policy and introducing a dual system (MRP and ROL) the migration of item headings would degrade the efficiency of both Systems and Policy. The major penalties would be:

a. Excessive stock levels.

b. Expensive communication systems.

c. Increasingly incorrect control methods.

d. Increased management intervention.

e. Increased manual intervention.

The ability to achieve a near optimum level of efficiency lies not only in the ability to classify inventory (which will provide increased efficiency until migration occurs) but to be able to reclassify inventory once the primal variables change. In order to cater for the classification and subsequent reclassification of inventory into the subsets, described in Chapter 5, it is necessary to have each item electronically tagged. This tagging process will relate to the identified variables within a given inventory which constrain the ability to maintain the laid down customer service. For any given inventory therefore the definition of service for each customer group must be agreed by the top level management. The other areas which must be simultaneously addressed are:

a. The degree of commitment.

b. Internal Policy.

c. Reliance, Service and Information needs of Suppliers. (Suppliers throughout the system).

Once these areas are defined the necessary product variables can be defined and ranged. The ranging of variables is important in that it allows automatic, computer, fine tuning of the inventory sub sets when policy, support or sub contractor performance varies.

The research into A vehicle spares found that without an electronic tag and therefore the ability to create subsets of inventory the following symptoms had occurred:

a. Total system overload.

b. Total reversion to manual control.

c. Total forecasting failure.

d. A breakdown of communications.

e. Stock of unwanted spares.

f. Stock out of vital spares.

g. Increased lead times.

h. Total management failure.

i. Incorrect policy decisions.

j. Crisis fire fighting.

k. Increased costs:

   (1) Downtime of equipment.

   (2) Data processing.

   (3) Storage.

   (4) Distribution (transportation).

   (5) Repair.

   (6) Overheads (communication, manpower etc).

The following graphs illustrate a cross section of the demand patterns of 4 subsets of inventory which the present system treats as a single homogeneous inventory.

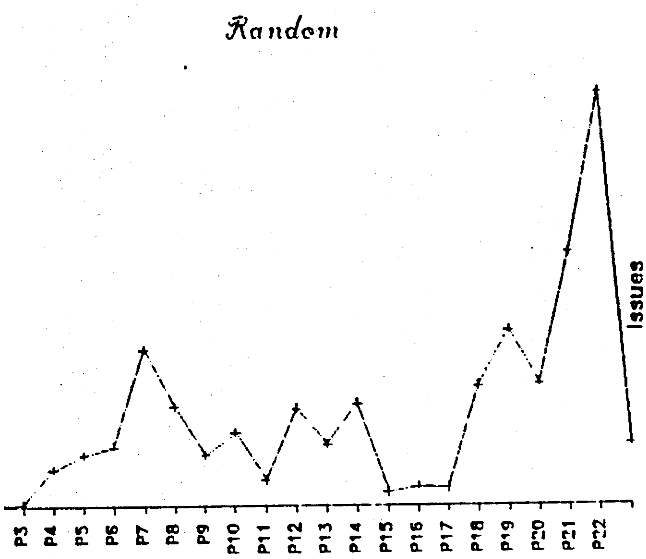


Figure 7.13

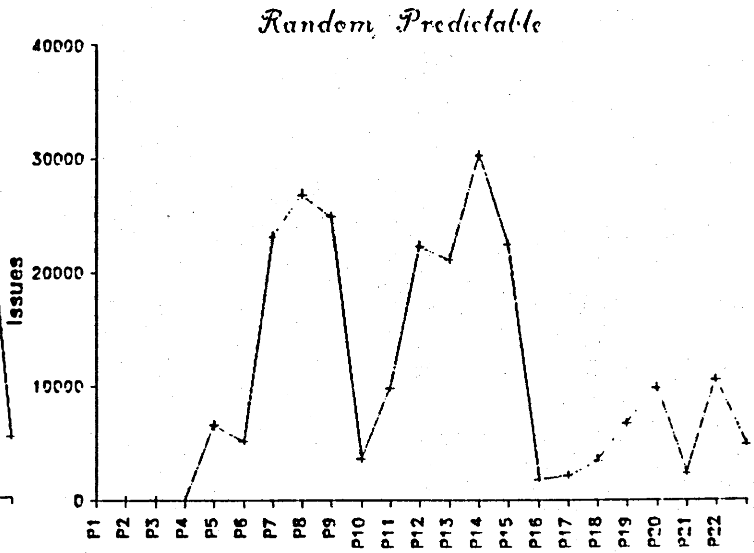


Figure 7.14

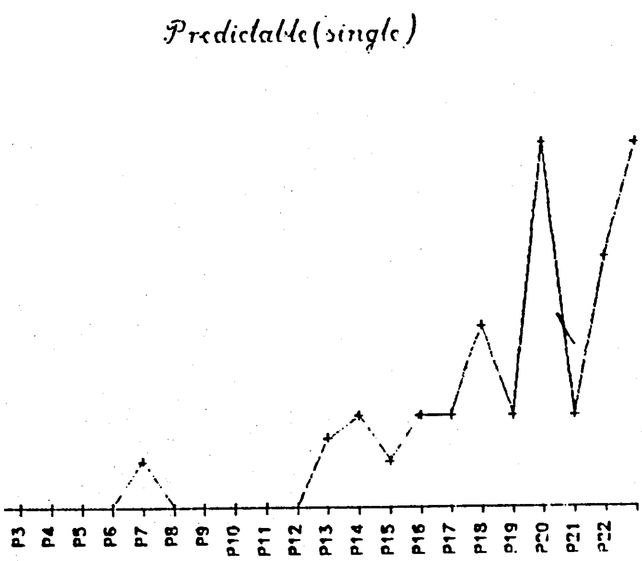


Figure 7.15

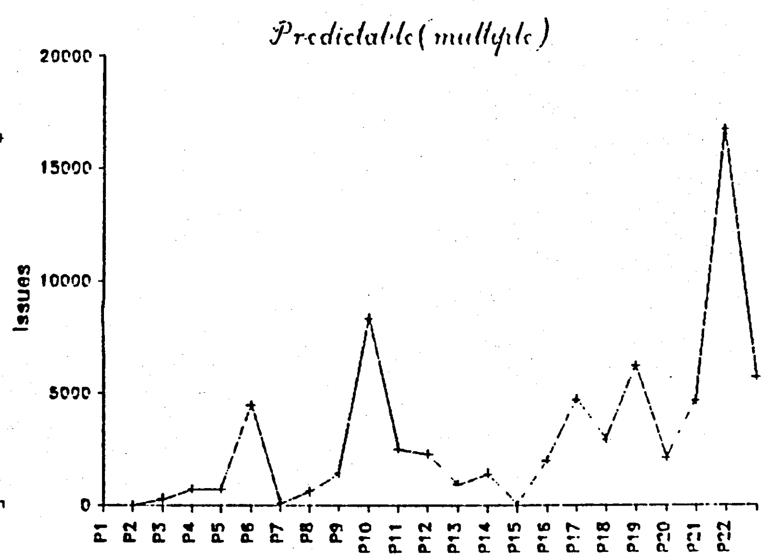


Figure 7.16

The classification of a sample of this inventory allowed the following management control decisions to be made:

a. Allocation of Forecasting method.

b. Degree of management or automatic control.

c. Method of Procurement.

d. Information needs of system and supplier to be assessed.

e. Stocking policy.

f. Method of Distribution.

The following efficiency increases occurred:

a. Dependent/predictable - Service Level 100%.

b. Random - increase in efficiency of computer control resulting in decrease of:

(1) Computer output.

(2) Management intervention.

(3) Instability.

(4) Crisis management.

(5) Negative communication.

c. Management - reversion to management function.

d. Creditability of supply system (this increase in faith should ultimately lead to a reduction in stocks held by customers 'Just in case').

During this research many examples of control system failures from military and civilian control systems were found. A selection of these are:

a. A reduction in price to clear end of line stock was reflected as a large offtake on the computer system. The purchasing staff rebought the item based on that months sales figures.

b. The acceptance of a small order for a component generated a purchase of 1 ton of raw material when a cwt would have sufficed.

c. A buy quantity of 2,000 requiring a delivery date in 14 months was placed. The delivery date was passed through to the forward customer who planned his usage. The actual contractor production rate was 50 per month.

7.4. Double ABC Analysis. Management time is increasing in importance as a variable within the inventory control formula. The goal of most organisations is to increase those items that can be computer controlled whilst decreasing the management required to manipulate those that fall outside the application of computer programs. The US Army have placed sufficient importance to this area that some of their classifications are centred around it (see Chapter 4 Paragraph 10). It was argued in Chapter 5 that an alternative approach for large inventories would be to carry out a double ABC analysis resulting in nine as opposed to three categories. This was the first

Test. In order to assess the possibly increased relevance of such an action after classification the inventory classification process was carried out after the double ABC analysis and this was the second Test.

7.4.1. ABC Analysis prior to Classification. The combined sample of 292 items was initially analysed into four groups:

A. - greater than £1000 throughput in 3 years.

B. - greater than £100 but less than £1000 throughput in 3 years.

C. - greater then £0 but less than £100 throughput in 3 years.

D. - no issues in 3 years.

This initial ABC gave management groups of:

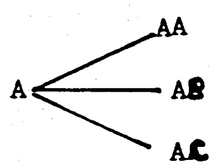
A. - 27% of sample 99.2% of cost.

B. - 21% of sample .7% of cost.

C. - 21.2% of sample .1% of cost.

D. 29.7½ of sample 0% of cost.

For small inventories this breakdown would give an acceptable management approach to control. For much larger inventories the degree of management effort would still be considerable and would involve over a $\frac{1}{4}$ of the inventory, in this case approximately 160,000 item headings. Each management group was then subject to a second ABC analysis such that



The results were as follows.

AA - 3% of sample represented 73% of Total Cost.

AB - 7.8% of sample represented 20.8% of Total Cost.

AC - 16% of sample represented 5.6% of Total Cost.

This second ABC reduces the managerial effort to cater for 73% of the inventory budget to just 19,726 or for 93.8% to 70,136.

The complete breakdown of analysis as far as CC is shown at Figure 7.17. Supporting data breakdown with further data is at Annex A to D. The results are graphically shown in Figure 7.18.

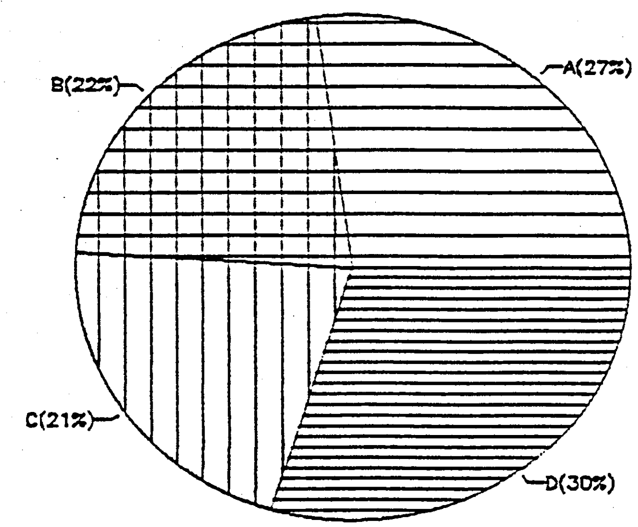
7.4.1. <u>ABC Analysis combined with Classification</u>. In a financially constrained environment expenditure on stock must be balanced against the policy of need. The double ABC analysis reduces the inventory into more manageable segments but does not ensure the correct utilisation of finance. By using the Non Significant/Significant indicator the inventory was further subdivided into 18 management groups. These groups are shown at Figure 7.19. The most useful and practical use of this final set is that the necessary managerial input to control the budget more accurately is reduced by almost 50% and in this instance full committal for those significant items represents 31% of the total budget. This further analysis after double ABC analysis therefore allows the manager to pose 'what if' questions against 18 separate subsets of the inventory. This allows him a greater degree of fine tuning when faced with the dilemma of salaami slicing his budget. It also allows for continual fine tuning as the year progresses to allow for unseen commitments. Using the full classifiction would enable even greater manipulation. When faced with a short period into which he must purchase the matrix could be configured using the repair dependent and LT indicator to eliminate those items on which no expenditure could be made. In the commercial field of course the non-significant significant grading could relate to percentage profit per sale. This and many other options would allow detailed analysis to be carried out quickly and simply thus allowing the manager to make decisions based on current factual information as opposed to out of date hard copy data.

SINGLE ABC	ITEMS	TOTCOST	TURNOVER	DOUBLE ABC CLASS	ITEMS	% POPN	% CLASS	CLASS TURNOVER	% POPN	% CLASS
				AA	9	3.082192	11.39241	2599992	72.8	73.32212
A	79	3545986	.9924639	AB	23	7.876712	29.11392	746135	20.9	21.04
				AC	47	16.09589	59.49367	199859	5.59	5.636
				BA	33	11.30137	51.5625	19724	.5520427	78.78
B	64	25037	.7007449	BB	18	6.164384	28.125	3720	.104	14.86
				BC	13	4.452055	20.3125	1593	.045	6.363
				CA	24	8.219178	38.70968	1506	.042	79.72
C	62	1889	.0528700	CB	18	6.164384	29.03226	292	.008	15.46
				CC	20	6.849315	32.25806	81	.002	4.28
D	87	0	0			29.79452				29.79452

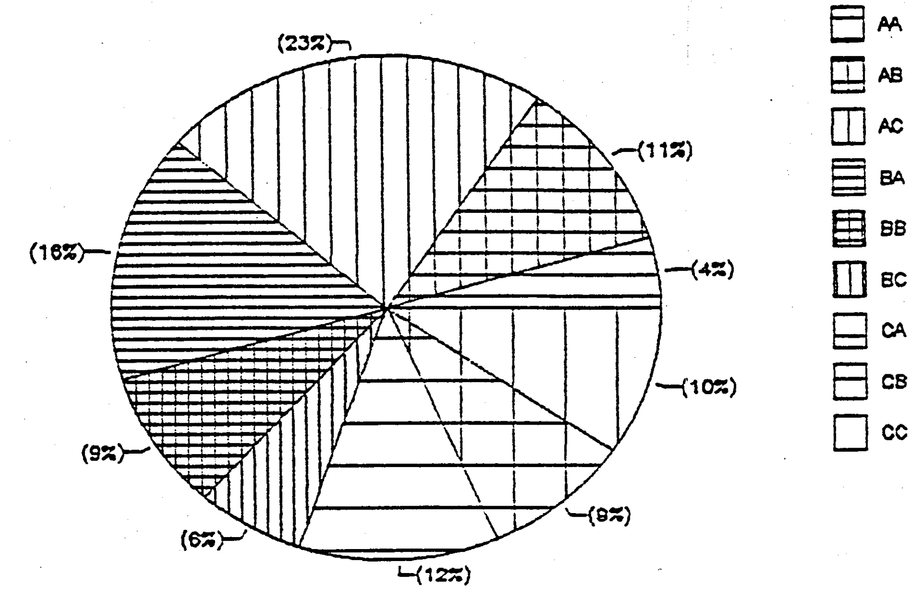
DOUBLE ABC ANALYSIS
PRIOR TO CLASSIFICATION

Figure 7.17

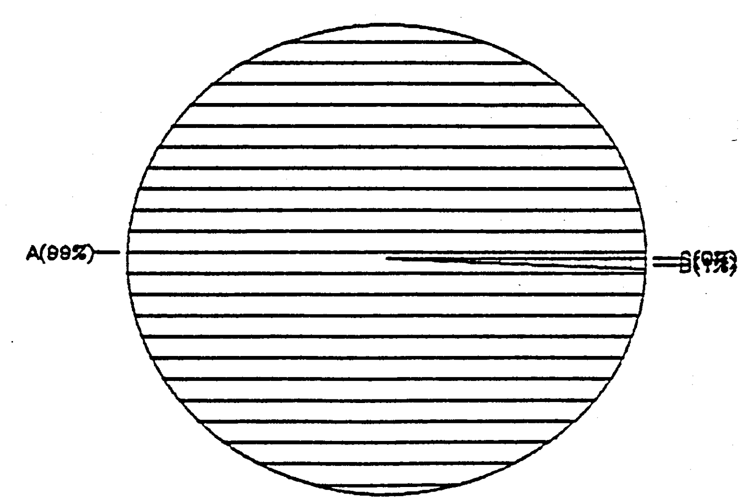
CLASSICAL ABC ANALYSIS



DOUBLE ABC ANALYSIS



CLASSICAL ABC ANALYSIS
THROUGHPUT VALUE



DOUBLE ABC ANALYSIS
THROUGHPUT VALUE

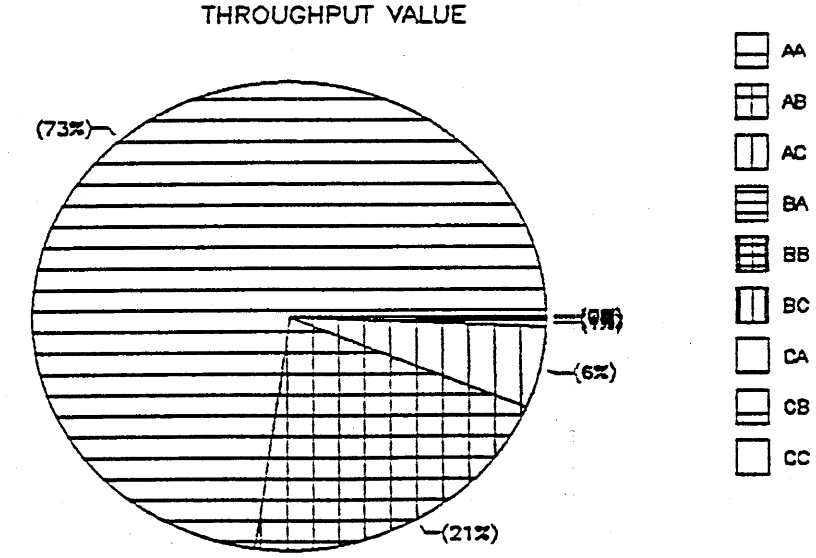
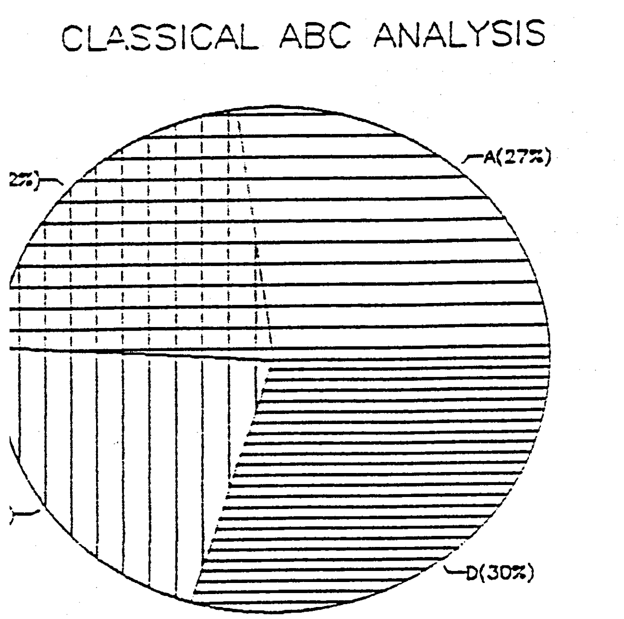


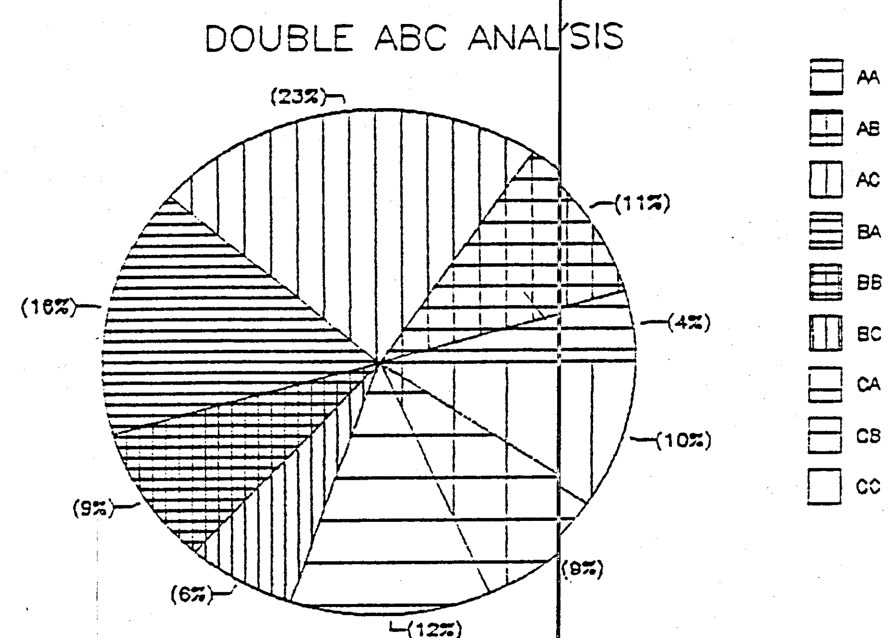
Figure 7-18

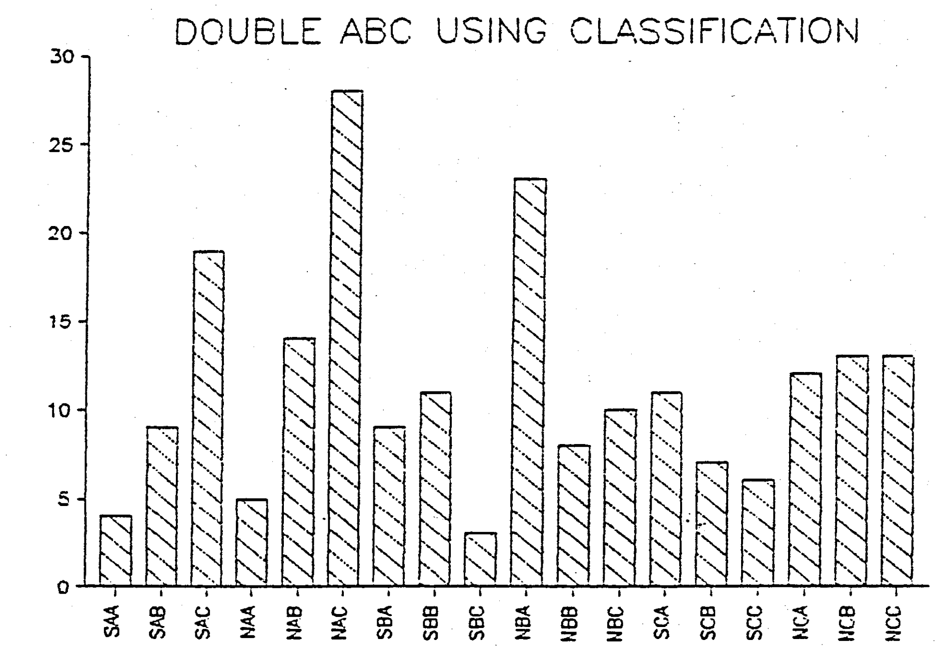
CLASS	TOTAL CLASS	% POPN	% CLASS	CLASS THROUGHPUT	% POPN	% CLASS
SAA	4.00	1.37	12.50	762707.00	21.35	68.34
SAB	9.00	3.08	28.13	266515.00	7.46	23.88
SAC	19.00	6.51	59.38	86851.00	2.43	7.78
NAA	5.00	1.71	10.64	1837286.00	51.42	75.61
NAB	14.00	4.79	29.79	479620.00	13.42	19.74
NAC	28.00	9.59	59.57	113008.00	3.16	4.65
SBA	9.00	3.08	39.13	6719.00	.19	71.21
SBB	11.00	3.77	47.83	2355.00	.07	24.96
SBC	3.00	1.03	13.04	362.00	.01	3.84
NBA	23.00	7.88	56.10	12691.00	.36	81.35
NBB	8.00	2.74	19.51	1679.00	.05	10.76
NBC	10.00	3.42	24.39	1231.00	.03	7.89
SCA	11.00	3.77	45.83	708.00	.02	80.64
SCB	7.00	2.40	29.17	141.00	.00	16.06
SCC	6.00	2.05	25.00	29.00	.00	3.30
NCA	12.00	4.11	31.58	761.00	.02	75.27
NCB	13.00	4.45	34.21	198.00	.01	19.58
NCC	13.00	4.45	34.21	52.00	.00	5.14

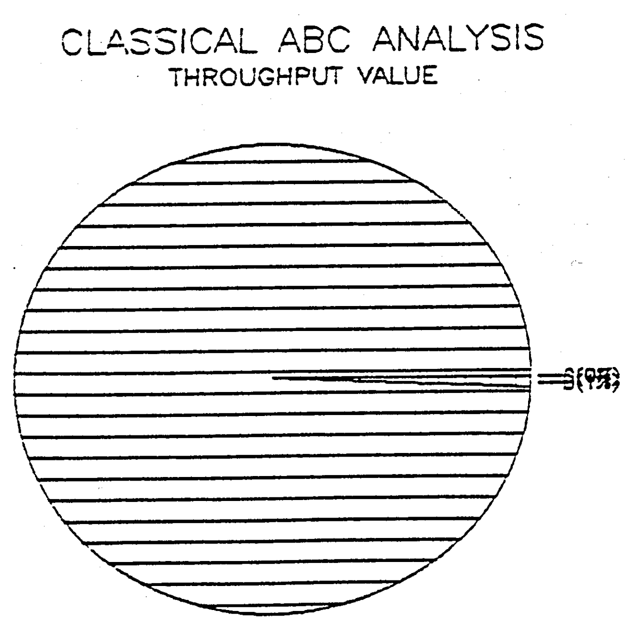
Double ABC after classification producing 18 Management Groups

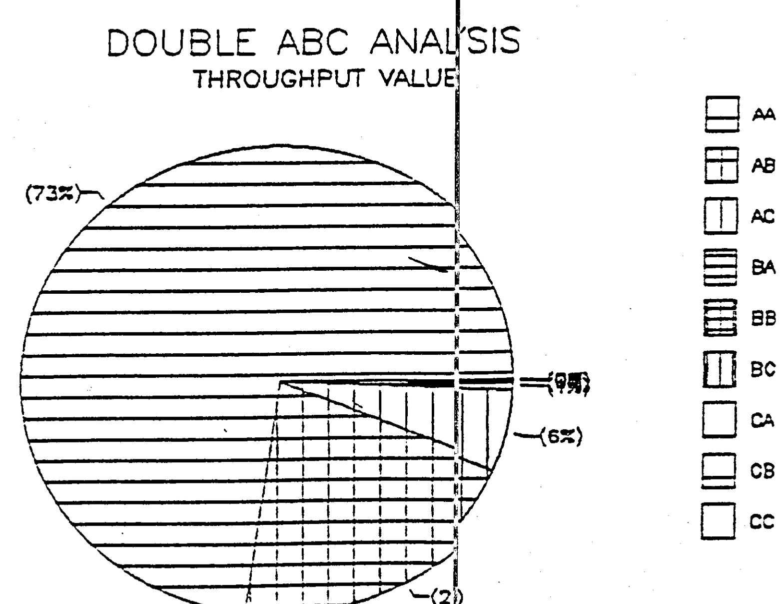
Figure 7-19


CLASSICAL ABC ANALYSIS
A(27%)
D(30%)


DOUBLE ABC ANALYSIS
(23%)
(11%)
(4%)
(10%)
(9%)
(12%)
(6%)
(9%)
(16%)
AA
AB
AC
BA
BB
BC
CA
CB
CC


DOUBLE ABC USING CLASSIFICATION
0
5
10
15
20
25
30
SAA
SAB
SAC
NAA
NAB
NAC
SBA
SBB
SBC
NBA
NBB
NBC
SCA
SCB
SCC
NCA
NCB
NCC


CLASSICAL ABC ANALYSIS
THROUGHPUT VALUE


DOUBLE ABC ANALYSIS
THROUGHPUT VALUE
(73%)
(6%)
AA
AB
AC
BA
BB
BC
CA
CB
CC

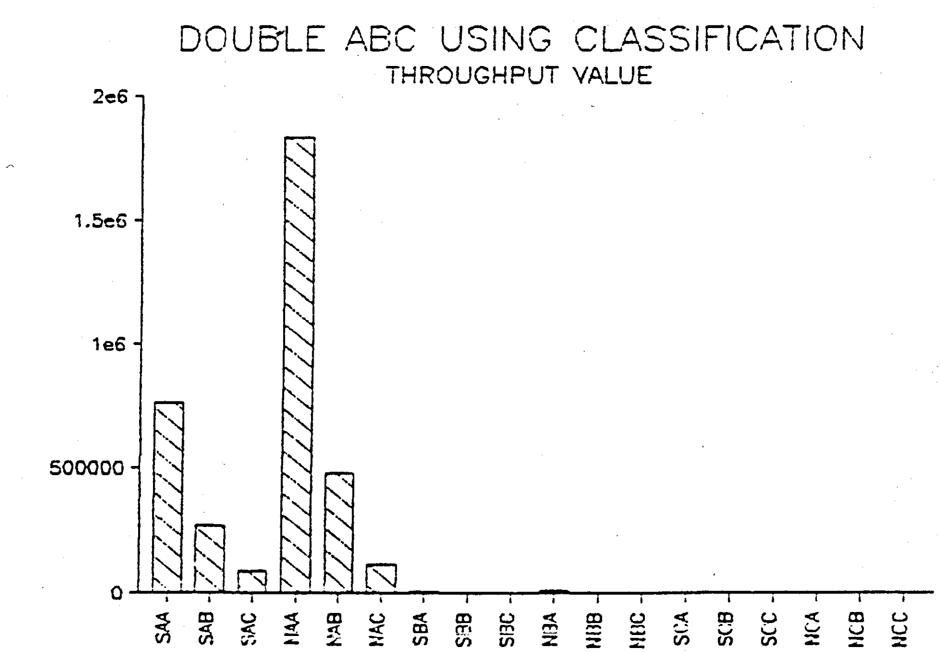

DOUBLE ABC USING CLASSIFICATION
THROUGHPUT VALUE
0
500000
1e6
1.5e6
2e6
SAA
SAB
SAC
NAA
NAB
NAC
SBA
SBB
SBC
NBA
NBB
NBC
SCA
SCB
SCC
NCA
NCB
NCC

Figure 7-19a

7.5. Manipulation of Output. Classification, as has already been demonstrated enables the inventory manager using models and pre-set filters to assemble the inventory into more homogeneous or responsive groups. These subsets of inventory represent the fulcrum between simple forecasting and the ability to employ expert systems. Whilst the move from a one inventory concept to a multitude of classified subsets represents a major improvement in the control of inventory it is only the beginning of the manipulative process which produces a final step towards the optimisation of stock holdings. The subset having been derived from a static model, bearing in mind that the relationship of each part to a subset is circumscribed by historical dynamic data, must now by means of a heuristic procedural model be matched against the most efficient management control/forecasting system. The static model can complete some of these actions. An item for example with no usage at all, and no predicted usage, belongs to a subset which responds equally well to any forecasting system. (Its relevant stock in this instance is dictated by its classification not by its historic dynamic data). Some subsets can be treated by the static model only, most however will respond more economically after a heuristic procedure had been followed. After a subset has been tagged by the heuristic procedure and a management control/forecasting method allocated it need only change when the management objectives cease to be met or migration between sub sets can be identified. When this situation occurs the complete subset will need to be re-evaluated to determine the cause of the error.

The following areas are discussed/anlaysed in the relation to the use of the model:

7.5.1. The application of MRP.

7.5.2. EOQ/ROL/ROQ.

7.5.3. Service Level.

7.5.4. Forecasting Options.

7.5.1. Application of MRP. The use of MRP is normally advocated in a manufacturing operation. Those who have attempted to use it within inventory control for service parts have had mixed success.
Subsets of inventory will be held to support discrete equipments or are occasionally so dependent upon each other within a subset as to represent a Bill of Materials. Classification will group these items into the same subset, thus making the use of MRP systems possible. Whilst a heuristic procedure may identify that the optimal forecasting system will be MRP it is probable that a more accurate trigger can be provided by management. The 'manufacturing' offtake within a subset will often appear as a totally random demand pattern. If sufficient 'manufacturing' is taking place then offtake may represent a stable pattern. This stable pattern can be dealt with equally by MRP or Simple Exponential Smoothing (SES). It is only when the 'manufacturing' offtake is irregular that SES is unable to cope. Small lots or limited seasonal production runs cannot be catered for with SES and produce out of control demand offtake. These control situations were

analysed in Chapter 6. The more logical method of demonstrating the accuracy of the hypothesis would be to take a DMC from Figure 6-1 with a biased engineering commitment. Company B are already doing this with regard to the use of MRP as an alternative to SES forecasting. The same process using the REME database, ARROW, could be followed for those engineering based subsets. The hypothesis however suggests that certain types of store, those that are dependent, would also be more economically and accurately controlled using MRP. From those DMC's in Figure 6.1 A4 met the criteria of irregular and unpredictable offtake. The range of stores were out of control using SES and could only meet the management availability constraints by the committal of capital on unnecessary reserves and safety stock. This DMC belongs to the more mundane side of the inventory referred to as General Stores. The range covers cordage, shackles, chains, paint, clothing etc. A most unlikely area in which a hi-tech system such as MRP would normally be employed. The A4 DMC covers spares and minor equipment to deliver men and materials for an airborne assault. The spares and equipment are non-complex low tech, require little engineering support but contain consumable/expendable, repairable and lifed parts. Each configuration in which the spares and equipment are used is governed by a Complete Equipment Schedule and Technical Drawings. This 'user handbook 'details what is required and how it is used in order that an equipment, weapon bundle or resupply container can be dropped from an aircraft. These documents were used as the bills of Material from which the forecast was drawn. The user of these equipment (Unit Y) with a strength in excess of 8,000 was then asked to produce his operation (war) requirement and annual training requirements. The constraining factor on the training usage was the availability of aircraft and from the availability of aircraft the expected production rate for the coming year was calculated. In order that a comparison could be made the complete section (A4) Provision Review Forms using EOQ/ROL and exponential smoothing on historic demand was output and loaded onto a micro. This sample numbered 554 item headings. Those items not included in A4 but essential to the configuration laid down were also added and this increased the sample to 844.

Even within this relatively small element of the inventory there were two clear discrete sub elements. These were the platforms with their component spares and the item headings used to retain equipments onto the platforms whilst air dropping. Both sub inventories attracted both a war scaling at an agreed fixed level and a random usage pattern. All of the part numbers were available for issue to any customer regardless of their role. After identification of the item headings from the BOM it was therefore possible to annotate discrete part numbers as only being required by 3 designated units who would therefore become the only entitled customers thus removing a hidden element of misuse and abuse of costly 'expense' items.

A sample of the printouts from the BOM and present FQD system are at Annexes A and B.

A comparison of cost savings is summarised below.

Range of Spares	EOQ costs	MRP Costs	Savings
Air Drop	3,110,867	727,910	2,382,957

These figures whilst indicative of a worthwhile saving must be taken into perspective. Firstly they do not represent the total savings that will be realised but relate purely to the above the line visible costs resulting from the adoption of MRP. The system change will decrease the capital employed, improve the estimates process and the allocation of the budget. Regarding stockholding there should be few if any surplus and a mimimum, if any, of stock outs, parts will not linger on shelves once obsolete as they will be readily identifiable from the BOM. Stockholding will become more exact and obsolescence can be phased over a set period. The manpower committed to control this range might decrease but these costs will be offset by the purchase of hardware and software and the training required to implement the system. A policy review and subsequent changes would be required and these in-part would contribute to the overall saving.

It is essential to note that for item headings subject to both dependent and independent demand then two forecasting methods/systems will be required. In most cases the dependent demand will be forecast using an MRP system. The independent demand forecasting system will relate to the randomness of the demand offtake.

7.5.2. Effect on ROL/ROQ.

7.5.2.1. Present Situation. The application of ROL and ROQ (EOQ) within the RAOC is explained in Chapter 2. The application is standard across all inventory items with the computer program facility to vary the factors $\frac{(Co)}{(Ch)}$ by individual DSM(A) Divisions. This facility is however, in practise, seldom used. The program is applied regardless of the product profile. It should be noted that the inventory contains some 30% non-moving parts and a standard ABC analysis gave a balance of 27, 22 and 21 percent for each group. The standard approach of applying ROL/ROQ manipulation by ABC groups would involve 3 samples of approximately 200,000 items. Clearly this is unacceptable but this approach will be considered and simulated.

As with the forecasting models the present ROL/ROQ calculations are applied blanket fashion. When the results are unfavourable, management intervention increases. This form of application coupled with decreasing cash limits has produced:

a. Unnecessary investment in stock.

b. Increasing stock out situations.

c. Increased levels of 'Safety Stock' (This safety stock may be hidden as LT stock or Free Stock).

d. Failure to ensure correct Trade Offs.

e. Increases in orders.

f. Increase in overheads (stock costs, hold, S&R, obsolence).

g. Crisis Management.

7.5.2.2. Method of Analysis. The data available was presented to a simulation model in 3 different formats.

1. Raw data in an unclassified format.
2. Sorted by an ABC analysis.
3. Sorted by a double ABC anlaysis.
4. In classification format after being processed by the hypothesis model.

The Results were then analysed to see whether:

a. ROL/ROQ can be matched to groups.

b. Stock reductions can be achieved.

c. 'Safety stocks' can be eliminated and at what risk.

d. Whether there is an effect on ordering policy.

7.5.2.3. Formula Used.

7.5.2.3a. ROQ/EOQ. The stock control function aims to minimise the cost of stock held whilst obtaining the maximum desired availability. The subject has been continually researched since its conception but is still represented as a trade off between Inventory cost relationships which are displayed as shown in Fig 7.20.

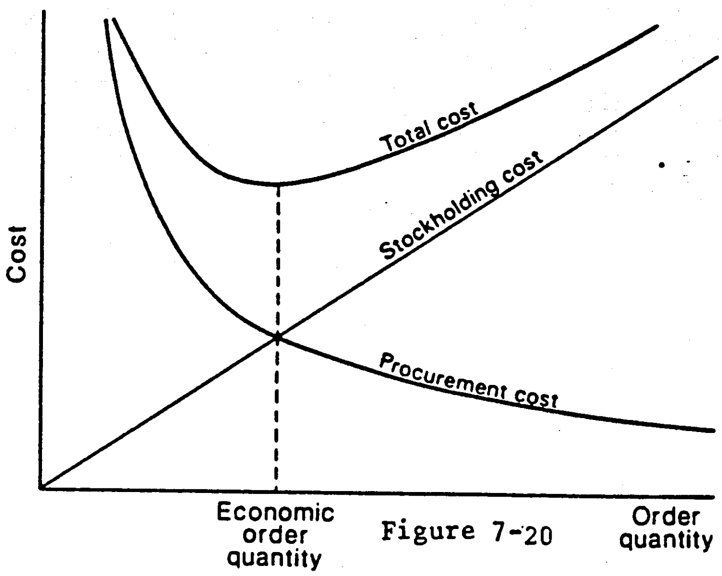


Figure 7-20

The following standard formula was used:

$$ROQ = \frac{2 \times Co \times R}{Ch \times P}$$

where Co = Cost to Order

Ch = Cost to hold

R = Annual Usage

P = Unit Price

Throughout the literature search whenever EOQ was referred to R was defined as the actual or average usage but never as the forecast usage. This presupposes that future usage will be identical to past usage or as most systems stated 'usage would remain within the standard poisson distribution curve. The formula is totally inadequate when dealing with slow moving (less than 10 demands per annum) or irregular random demands, which whilst clearly recognised does not prevent inventory managers from continuing to use the formula!

7.5.2.3b. ROL. The ROL formula has a single purpose. It is to decide that moment in time at which when an order is placed there will be sufficient stock remaining to meet the desired service level before the next receipt of stock is available for issue. It is however the most subjective decision made within inventory control. It is the vortex at which the forecaster, provisioner, management, procurer and supplier in turn contribute to the failure or success of an inventory to meet its objectives. JIT and MRP are both based on accurately predicting it and then by trade off reducing it. The ROL formula varies in complexity from company to company. In one of its simplest formats it is represented as:

ROL = (MTLT x r) + R   MTLT

where MTLT = Mean Total Lead Time

r = Mean demand

= standard deviation of the demand.

k = The value representing the probability percentile (set by management) which will not be exceeded by the demand rate.

<u>7.5.2.4. Data Base</u>. That data already downloaded from the CICP system onto microcomputers was readily available. It constituted all that data accessible to the main frame whilst carrying out similar calculations. The daily issue and receipt activity is not held but represented by aggregated figures. In order to carry out simulation it was necessary to rebuild some of this data into its correct sequence. Some data which was required is not held and this was derived from calculations built into the simulation model. (These are marked *)

.receipts per quarter for 22 quarters*

.average past issues

.min stock

.max stock

.standard deviation of demand*

.co-efficient of variation*

.Average Demand

.Number of Demands placed

7.5.2.5. Simulation Model. The computer program initially written was designed to simulate the present system. This was tested against item headings for which 66 months of data were available. Once the program was simulating those offtakes laid down in system paper 29 the following sub-routines were added:

1. Co-efficient of Variation.
2. Standard Deviation of Demand.
3. ROL recalculation sub-routine.
4. ROQ recalculation sub-routine.

The model was built to carry out a double print sequence for each item heading. The first produced a print of the present control system. The second produced a print using different ROQ and ROL formulae.
A program listing of the model is at Annex C.

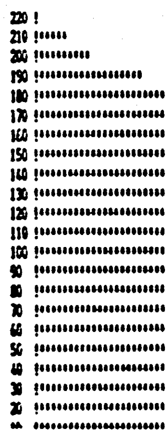
7.5.2.6. Raw Data. The raw data experiment was time consuming, confusing and mainly negative. As soon as the sub routines were amended to improve the performance of one item heading (or a group). This would destroy the stability of the remaining item headings. After numerous attempts including bracketing using abnormal values no benefits were obtained. The experiment revealed 2 significant problems with using the ROQ/ROL system for all inventory. The first example to confuse the model was the depth of stock. To quote one example only with a Quarterly demand of 1.55 and a stock level of 210 representing 30 years worth of stock. The results are shown below.

1	1	0	213	0
2	1	0	212	0
3	0	0	212	0
4	0	0	212	0
5	2	0	210	0
6	1	0	209	0
7	2	0	207	0
8	2	0	205	0
9	4	0	201	0
10	3	0	198	0
11	0	0	198	0
12	2	6	196	0
13	1	0	195	0
14	1	0	194	0
15	0	0	194	0
16	0	0	194	0
17	2	0	192	0
18	1	0	191	0
19	2	0	189	0
20	2	0	187	0
21	4	0	183	0
22	3	0	180	0

ACTUAL STOCK LEVEL FOR PART NO. 253099806822B BRACKET

R.O.L. 123 R.O.Q. 32 PRICE 569.122
AVSTOCK 198.7273
AVERAGE STOCK VALUE : 113100.1
COEFFICIENT OF VARIATION : 6.77
DEMANDS ARE WITHIN LIMITS OF SES

AVER.DEMAND : 1.55
S.D. OF DEMAND : 1.20

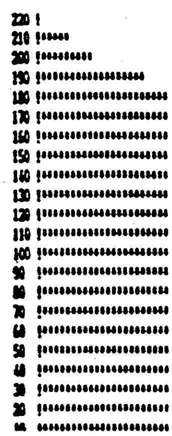


1	1	0	213	0
2	1	0	212	0
3	0	0	212	0
4	0	0	212	0
5	2	0	210	0
6	1	0	209	0
7	2	0	207	0
8	2	0	205	0
9	4	0	201	0
10	3	0	198	0
11	0	0	198	0
12	2	0	196	0
13	1	0	195	0
14	1	0	194	0
15	0	0	194	0
16	0	0	194	0
17	2	0	192	0
18	1	0	191	0
19	2	0	189	0
20	2	0	187	0
21	4	0	183	0
22	3	0	180	0

SIMULATED STOCK LEVEL FOR PART NO. 253099806822B BRACKET

R.O.L. 40 R.O.Q. 3 PRICE 569.122
AVSTOCK 198.7273
AVERAGE STOCK VALUE : 113100.1
COEFFICIENT OF VARIATION : 0.77
DEMANDS ARE WITHIN LIMITS OF SES

AVER.DEMAND : 1.55
S.D. OF DEMAND : 1.20



Simulation Model Results

Figure 7.21

The second example which the model could not cope with was excessive lead time. A lead time of 58 months, which is not atypical destroyed the simulation and the ROL/ROQ formulae. The results are shown below:

14792	0	-14792	16679	1	14792	0	-14792	18700
11798	0	-26590	33358	2	11798	0	-26590	37400
17230	0	-43820	50037	3	17230	0	-43820	56100
21365	0	-65185	66716	4	21365	0	-65185	74800
13812	0	-78997	83395	5	13812	0	-78997	93500
20152	0	-99149	100074	6	20152	0	-99149	112200
20964	0	-120113	116753	7	20964	0	-120113	130900
18948	0	-139061	133432	8	18948	0	-139061	149600
11413	0	-150474	150111	9	11413	0	-150474	168300
9616	16679	-143411	150111	10	9616	18700	-141390	168300
17230	16679	-143962	150111	11	17230	18700	-139920	168300
320	16679	-127603	150111	12	320	18700	-121540	168300
17230	16679	-128154	150111	13	17230	18700	-120070	168300
21365	16679	-132840	150111	14	21365	18700	-122735	168300
13812	16679	-129973	150111	15	13812	18700	-117847	168300
20152	16679	-133446	150111	16	20152	18700	-119299	168300
20964	16679	-137731	150111	17	20964	18700	-121563	168300
18948	16679	-140000	150111	18	18948	18700	-121811	168300
11413	16679	-134734	150111	19	11413	18700	-114524	168300
9616	16679	-127671	150111	20	9616	18700	-105440	168300
17230	16679	-128222	150111	21	17230	18700	-103970	168300
320	16679	-111863	150111	22	320	18700	-85590	168300

TOCK LEVEL FOR PART NO. 4.020991208166E12 ROPE

44265 R.O.Q. 16679 PRICE .133
-111717.8
STOCK VALUE = -14858.46
ENT OF VARIATION = 0.40
ARE WITHIN LIMITS OF SES

AND = 14940.45
DEMAND = 5963.89

10 20 30 40

SIMULATED STOCK LEVEL FOR PART NO. 4.020991208166E12 ROPE

R.O.L. 166315 R.O.Q. 18700 PRICE .133
AVSTOCK-103358.2
AVERAGE STOCK VALUE = -13746.64
COEFFICIENT OF VARIATION = 0.40
DEMANDS ARE WITHIN LIMITS OF SES

AVER.DEMAND = 14940.45
S.D. OF DEMAND = 5963.89

: !

1 10 20 30 40

<u>Simulation Model Results 2</u>

Figure 7.22

7.5.2.7. Recommendations and Conclusions.

a. The ROL/ROQ formula should not be used in a blanket fashion.

b. Considerable improvements in stock availability and reductions in stock costs can be achieved if the formula are applied in a logical manner.

c. The formula perform best when used in homogeneous grouped classified item headings.

d. The formulae are not robust and are incapable of handling.

1. Slow moving items (less than 7 demands per annum).
2. Irregular random demands.
3. Item headings with stock in excess of 3 years demand.
4. Item headings with lead times in excess of 12 months.
5. Item headings experiencing dependent and independent demand.

7.5.3. Service Level. As with other elements of System 3 and also the majority of the research companies Service Level was laid down as an arbitary figure, more as a management goal than a realistic figure. There was however a serious dichotomy between the commercial and the military interpretation of service level, not with the definition, and is related directly to the customer. The difference between captive and free customers is covered extensively in Chaper 4. Without classification it is not possible to develop policy regarding differing levels of service. The set service level (goal) in system 3 for all items less those purchased from American sources (85%) is 95%.

With a high percentage of the inventory experiencing irregular random demand, coupled with erratic lead times, the safety stock to provide this degree of service is £46.5 Million. The elimination of some of this safety stock is only possible if alternative service levels can be substituted. This is not possible via an ABC categorisation and can only be achieved by a direct classification route. The model was therefore amended to automatically re-allocate a service level. Whilst this will be a management policy decision which can be varied the settings for the model were:

Significant lower constraint 80% upper constraint 100%
(Significant dependent does not incur a service level setting as it is automatically set at 100%)

Insignificant lower constraint 40% upper constraint 60%
(Wherever an insignificant item heading is held forward and greater than 3 months stock are held and LT $<$ 4 month Service Level = 0).

16 PLATFORM REQUIREMENTS(PLATA) M E D I U M P L A T F O R M

EC	NATO NUMBER	DESIGNATION	CRS	5101	5111	5111 W16	5111 W17	5130	5131	5211	5211 W13	5215	5310	5311	5420	5446	5510	5511	5512
		ANNUAL TRG QTY(ATQ)		8	30	9	54	12				30			6	3			
B16	1670991022338	HOOK TENSIONER 5000LB		1	9	16	8	17	1	9	8	22			26	12	20	79	1
B16	1670991022486	PROTECTION BOARD													1				3
B16	1670991022596	PAD ENERGY DISSIPATING 1/2IN	AR			2		1							AR	8	8	53	AR
B16	1670991022656	STRAP WEBBING 5000LB 7FT		1	5	12	6	22	1	5	6	34			34	5	17	72	1
B16	1670991022657	STRAP WEBBING 5000LB 12FT		1	4	12	3	5	1	6	3	6			1	6	7	41	1
B16	1670991022658	STRAP WEBBING 5000LB 15FT			2	2	2	2		2	2							14	
B16	1670991025219	CHAIN ASSY SL 5000LB 7FT		12	24	24	24	14	16	24	24	26			20	24	4	34	8
B16	1670991025220	CHAIN ASSY SL 5000LB 12FT		6	4	4	4	2		2	4	20			8	16	4	14	4
B16	1670991026509	CHAIN ASSY SL 5000LB 15FT																30	4
B16	1670991026535	CHAIN ASSY SL 10000LB 7FT																	
B16	1670991026536	CHAIN ASSY SL 10000LB 12FT																	
B16	1670991026537	CHAIN ASSY SL 10000LB 15FT																	
B16	1670991028971	COUPLING TENSIONER QR 5000LB		18	28	28	28	16	16	26	28	40			24	42	8	90	16
B16	1670991031950	SKID DOOR L/H FRONT RH REAR	2																
B16	1670991032792	SKID DOOR R/H FRONT LH REAR	2																
B16	1670991043473	STRAP EXTENSION 9FT		1	1	1		1	1	1						1	1	4	
B16	1670991044583	ADAPTOR RISING (AFT LINKAGE)																	
B16	1670991044584	CONNECTOR 40000LB	6	6	6	6	6	6	6	6	6	6			6	6	6	24	6
B16	1670991052130	COVER ACCESS AIRBAG RH REAR	1																
B16	1670991052131	COVER ACCESS AIRBAG LH REAR	1																
B16	1670991057115	WIRE ROPE ASSY SL .08IN DIA	1	1	1	1	1	1	1	1	1	1			1	1	1	4	1
B16	1670991057117	DROP BAR SKID DOOR	4																
B16	1670991203405	ADAPTOR TRUCK CARGO						2											
B16	1670991203406	BAG CUSHIONING			1	1	1			1	1							4	
B16	1670991203412	BOARD PACKING			1	1	1			1	1							2	
B16	1670991204904	BEAM SHOCKSTRUT		2					2										
B16	1670991207994	TUBE SHOCKSTRUT 6IN	AR	18	6	6	2	14	20	6	2	16						4	
B16	1670991208110	WRAPPING SLING						4								3		11	
B16	1670991208245	BOARD SUPPORTING HONEYCOMB															3		
B16	1670991208246	BOARD SUPPORTING HONEYCOMB																4	
B16	1670991208447	BLOCK					4				4								

)MC	NSN	ITEM	CLASS	P]	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	STOCK	FQD	LTCPRICE	
B10	1670991022338	HOOK	3	574	450	39	231	235	54	347	303	220	56	354	308	2659	194.73	12	7.792
B10	1670991022486	BASEBOARD	3	442	450	200	550	200	542	105	1195	271	332	479	250	2074	399.49	11	34.322
B10	1670991022596	PAD	3	0	3300	3000	1277	0	0	1000	0	3000	3000	9000	3500	10147	3298.09	10	2.66
B10	1670991022656	STRAP	3	0	0	0	0	24	0	0	0	80	0	17	20	1618	12.52	12	39.72
B10	1670991022657	STRAP	3	8	0	0	0	24	0	0	0	0	0	6	0	404	4.77	14	43.71
B10	1670991022658	STRAP	3	143	0	7	8	24	1	8	22	22	0	254	61	1390	14.31	12	20.305
B10	1670991025219	CHAINASSY	3	59	386	29	39	1	270	301	20	31	0	115	36	2703	103.3	13	7.61
B10	1670991025220	CHAINASSY	3	119	107	48	93	40	99	258	90	18	2	117	26	777	81.86	9	10.98
B10	1670991026509	CHAINASSY	3	24	27	87	0	20	0	24	0	0	12	114	37	557	34.66	12	20.104
B10	1670991026535	CHAINASSY	3	610	117	177	429	96	384	1455	157	316	267	545	412	204	333.06	6	8.78
B10	1670991026536	CHAINASSY	3	298	153	338	54	100	227	1013	45	73	0	338	150	144	174.36	13	12.8
B10	1670991026537	CHAINASSY	3	365	255	313	249	131	281	1181	115	34	61	1659	225	2226	220.36	11	15.97
B10	1670991028971	COUPLING	2	122	406	161	117	325	326	528	13	38	19	268	89	2969	192.58	12	51.12
B10	1670991031950	SKIDDOOR	3	0	80	0	4	3	61	0	0	12	0	20	0	814	13.83	30	283.62
B10	1670991032792	SKIDDOOR	3	8	86	4	32	46	62	0	0	12	0	20	0	606	19.39	29	283.62
B10	1670991043473	STRAP	3	0	0	0	0	0	0	28	14	10	57	8	0	265	14.7	16	21.883
B10	1670991044583	ADAPTOR	3	0	0	0	0	0	0	0	2	0	1	1	0	4	.04	12	391.515
B10	1670991044584	COUPLING	3	14	105	45	40	200	24	212	137	32	100	50	70	2193	85.7	18	17.448
B10	1670991044584	COUPLING	3	14	105	45	40	200	24	212	137	32	100	50	70	2193	85.7	18	17.448
B10	1670991052130	COVER	3	0	30	0	0	0	3	13	50	0	20	0	30	314	11.46	26	12.436
B10	1670991052131	COVER	3	0	90	0	0	0	3	17	25	0	21	0	1	367	10.87	28	12.436
B10	1670991057115	ROPEASSY	3	0	0	78	55	130	40	30	20	40	100	0	0	133	45.14	6	26.6
B10	1670991057117	DROPBAR	3	12	32	0	0	0	12	96	6	0	0	171	34	0	42.18	10	31.49
B10	1670991203405	ADAPTOR	3	8	0	0	0	0	0	0	0	0	0	10	0	88	12	18	.638
B10	1670991203406	BAG	3	0	0	0	0	0	0	0	0	0	0	0	0	87	3	16	69.216
B10	1670991203412	BOARD	3	0	0	0	60	0	0	0	0	0	0	0	0	196	8.15	5	1.689
B10	1670991204904	BEAM	3	0	0	0	0	0	0	0	0	0	10	0	0	199	.93	6	2.807
B10	1670991207994	TUBE	3	0	100	154	0	0	292	130	0	100	0	200	0	7042	106.86	16	1.33
B10	1670991208110	SLING	3	0	40	0	0	0	0	0	22	0	6	0	0	864	3.85	12	3.523
B10	1670991208245	BOARD	3	0	0	0	0	0	0	0	0	0	0	0	0	24	1	8	3.599
B10	1670991208246	BOARD	3	0	0	0	0	0	0	0	0	0	4	4	0	12	1.12	11	14.235

```
10 ON ERROR GOTO 890
20 PRINT "STOCK SIMULATOR WITH ROL/ROQ CALCULATION"
30 PRINT "---------------------------------------"
40 PRINT : PRINT
50 PRINT : INPUT "DATA FILE TO USE ";DF$
60 OPEN DF$ FOR INPUT AS £1
70 LPRINT "DATA FILE USED ";DF$ : LPRINT
80 DIM DEMAND(60),RECEIPT(60),ADJUST(60),STOCK(60)
90 DIM PRECEIPT(200)
100 IF EOF(1) THEN 910
110 INPUT £1,PN$,DESC$,FINSTOCK,PRICE,ROL,ROQ,LTIME
120 PASS= 0
130 PRINT"                    --- PART NO.        ";PN$;"     ---"
140 FOR I=1 TO 22
150 INPUT £1,DEMAND(I)
160 NEXT I
170 IF LTIME=0 THEN PRINT "CANNOT SIMULATE NO L/T DATA ":GOTO 110
180 TOTD=0 : TOTR=0 : TOTA=0 : SX2=0 : AVTOT=0
190 FOR I=1 TO 22
200 IF DEMAND(I)<0 GOTO 220
210 AVTOT=AVTOT+DEMAND(I) : SX2=SX2+DEMAND(I)*DEMAND(I)
220 TOTD=TOTD+DEMAND(I)
230 NEXT I
240 PRINT "*****   TOTAL DEMAND (22 QTRS)",TOTD
250 AVDEM=AVTOT/22 : SDDEM=SQR(SX2/22-AVDEM*AVDEM)
260 PRINT " ** ANNUAL DEMAND = ";AVDEM*4,"** PRICE = ";PRICE
270 PRINT "AV.DEM./QTR";AVDEM
280 ROLC=0
290 COEFF = 0
300 ROQC=0
310 PRINT "S.D. OF DEM. = ";SDDEM
320 STOCK(0)=FINSTOCK
330 MXST=0 : MNST=0 :QOO=0 :AVSTOCK=0
340 FOR I=1 TO 22
350 RECEIPT(I)=0:STOCK(I)=0
360 NEXT I
370 PRINT
380 FOR I=1 TO 22
390 STOCK(I)=STOCK(I-1)-DEMAND(I)+RECEIPT(I)
400 QOO=QOO-RECEIPT(I)
410 IF STOCK(I)>MXST THEN MXST=STOCK(I)
420 IF STOCK(I)<MNST THEN MNST=STOCK(I)
430 IF STOCK(I)+QOO<=ROL THEN RECEIPT(I+LTIME)=RECEIPT(I+LTIME)+ROQ:QOO=QOO+ROQ
440 LPRINT I,DEMAND(I),RECEIPT(I),STOCK(I),QOO
450 AVSTOCK=STOCK(I)+AVSTOCK
460 NEXT I
470 MSTOCK=(AVSTOCK/22)
480 LPRINT:LPRINT:LPRINT
490 IF PASS=0 THEN LPRINT "ACTUAL STOCK LEVEL FOR PART NO. ";PN$;"    ";DESC$
500 IF PASS=1 THEN LPRINT "SIMULATED STOCK LEVEL FOR PART NO. ";PN$;"    ";DESC$
510 LPRINT
520 LPRINT "R.O.L. ";ROL;"  R.O.Q. "ROQ;"  PRICE ";PRICE
530 LPRINT "AVSTOCK";MSTOCK
540 STOCKPRICE = MSTOCK*PRICE
550 LPRINT"AVERAGE STOCK VALUE = ";STOCKPRICE
555 COVAR =SDDEM/AVDEM
557 COEFF=COVAR
560 LPRINT USING "COEFFICIENT OF VARIATION = £££.££";COEFF
570 IF COEFF >1 THEN LPRINT "DEMANDS ARE OUTSIDE NORMAL LIMITS OF SES"
580 IF COEFF <1 THEN LPRINT "DEMANDS ARE WITHIN LIMITS OF SES"
590 LPRINT
620 LPRINT USING "AVER.DEMAND = £££££.££";AVDEM
630 LPRINT USING "S.D. OF DEMAND = £££££.££";SDDEM
640 LPRINT
650 STINC=INT(MXST/20)
660 STINC=5*INT(STINC/5)
670 IF STINC=0 THEN STINC=1
680 MXST=STINC*(INT(MXST/STINC)+1)
690 FOR I=MXST TO 1 STEP -STINC
700 LPRINT I;TAB(6);"!";
710 FOR J=1 TO 22
720 IF STOCK(J)>=I THEN LPRINT "*";ELSE LPRINT " ";
730 NEXT J
740 LPRINT " "
750 NEXT I
760 LPRINT " "
770 LPRINT "      1        10        20        30        40 "
780 PASS=PASS+1
790 IF PASS=2 GOTO 100
800 CO=20
810 CH=.17
820 ROQC =INT((SQR((2*CO*4*AVDEM)/(CH*PRICE)))+(3*SDDEM)+(LTIME*AVDEM))
830 ROLC=INT((LTIME*AVDEM)+(AVDEM*2))
840 ROQ=ROQC
850 ROL=ROLC
860 LPRINT:LPRINT:LPRINT
870 IF EOF(1) THEN GOTO 910
880 GOTO 320
890 IF ERL=110 THEN RESUME 910
900 PRINT "ERROR ";ERR;" AT LINE ";ERL
910 END
```

CHAPTER 8. EFFECT OF IMPLEMENTATION OF HYPOTHES INCLUDING CLASSIFICATION

8.1. Introduction. Classification, enabling the inventory to be sub divided into homogeneous groups was and is the core of this research. If the research can be regarded as successful then it is necessary to take the study one stage further and demonstrate what implications the findings will have upon the inventory. Will control be simpler, will forecasting become easier and more accurate, what will be the cost to implement and what will be the return or bottom line.

8.2. Micro Inventory Command and Control System . The pursuit of optimal inventories is a past time of academics. The real world is composed mainly of those who resist change, especially that which they do not comprehend. The Holy Grail for inventory control and forecasting is however to build the ultimate system which allows total manipulation of every item within the inventory and produces the optimum level for each item with regard to stocks and service level. The original definition almost unchanged since the 1920's of the right item in the right place at the right time at the best price has always consumed managerial effort. Distribution technology has concentrated on reducing warehouse costs, stock levels, transportation and manpower input. The evolution from EOQ through DRP, MRP, TDC and more lately ILS have not always brought full benefits, especially in managerial effort.

The model proved to have the facility to segregate items by their individual profile and demand characteristics. What was eventually produced was a crude but efficient Micro Inventory Command and Control System. The complexity of the model, with regard to the step functions, not mathematical calculations, increases the computer time required for control. The system cannot be implemented using certain companies present hardware and configurations. Alternative options are however to:

a. Subdivide the inventory into its homogeneous groups and control these on smaller faster more modern computers.

b. Subdivide the inventory into active and passive and only control those active items (lock the door and throw the away the key).

c. Replace the existing hardware.

The most crucial element of change in the present time is however the bottom line with regard to finance. The alternative method of viewing inventory prepared in the thesis and the options possible for control allow the modern day progressive company the facility to analyse their stock in an alternative way. Inventory is and will remain an overhead within most if not all organisations. It has been argued that inventory can never be regarded as a profit centre but neither must it be regarded as a loss area. The more fashionable view is to regard it as a value adding area of business. It may therefore be more correct to say that inventory should add the maximum value for the minimum cost.

1. Variable
   Stock
   Costs

2. Variable
   Management
   Costs

3. Variable
   Warehouse
   Costs

4. Fixed
   Overhead
   Cost

The benefits of the proposed system allows reductions in the 3 main cost bearing areas (1-3). The initial significant saving will occur on first implementation. This will not be achieved without some minor penalty. Some stock which is subsequently required will be removed from the inventory, some will be retained which should be removed. The risks are however, when compared with the savings, acceptable. The saving within the 3 areas will cover sufficient extra major equipment/expenditure to alow increased cover should mistakes be made. The expected savings in the 3 areas are:

a. Stock costs.

b. Mgt costs.

c. Warehouse costs.

These figures are based on a full sample run of 1000 and have deliberately been biased towards safety. (For those items which were considered as being either significant or insignificant a grading of significant has been given). It should also be noted that for those significant items with zero usage over a 3 year period disposal has not been included.

8.3. Alternative Forecasting Techniques. The use of multiple forecasting systems can increase the complexity and cost of inventory management out of proportion to the need to be totally accurate. The model in Chapter 7 was constructed with this principle as a constant constraint. The cut off level for what is insignificant is extremely difficult to ascertain or justify. If the cost to order and the cost of disposal are both for example £40 is there any saving in disposing of an asset worth £1. Obviously it is dependent on the cost to hold, the management effort and the number of similar type items in the inventory. Assuming the inventory is well run and does not contain excessive non-moving stock then it would be unacceptable to change the forecasting method for such an item as this would be a waste of time and effort. Within the context of the hypothesis forecasting accuracy is worth pursuing for those items which are 1. significant 2. Expensive, 3. fast moving. There is a tendency within public bodies, which is not reflected in profit orientated systems, to concentrate considerable effort on slow moving erratic usage items. Whilst these may represent a significant percentage of the inventory (between 20 and 60% of the companies studied) the throughput is less than 1% of the total budget. Their forecasting is of no interest but their retention in the inventory represents a constant out turn for minimal gain. Classification once implemented will allow considerable weeding of these parasitic elements of inventory. Those items which are already forecastable/stable are not of any further interest as they can be dealt with simply using one of many forecasting options. The first 4 stages of the model therefore removed from the field for analysis those items already catered for by the simplest system.

Sample 1 - $\frac{87}{97} \times 100 = 79.6\%$

Sample 2 - $\frac{78}{98} \times 100 = 89.6\%$

Sample 3 - $\frac{99}{100} \times 100 = 99\%$

Those still remaining fell into the A and B categories of the Pare to analysis. Their demand patterns were not accurately forecastable using a simple exponential smoothing system. Even though no attempt has been made to use any other system to forecast them over the last 15 years! The argument against any additional effort might perhaps have been that they represent only 4% of the inventory! Their turnover however represents between 50% and 80% of budget expenditure (in the research companies).

All of the research companies bar 2 use simple exponential smoothing (SES). Their systems all depended on the validity of historical data, whether MRP or SES was being used. MRP when used with Time Scheduling appeared to represent a significant improvement but this could not be verified as data from the previous control system was not credible (between 50 and 70 percent accurate). The majority of the companies have found that their demand pattern has been influenced by their need to operate their base warehouses in both a wholesale and retail fashion. Through varying degrees of complexity these two unrelated methods of distribution have been combined to create a demand pattern. The most drastic but obvious way to resolve this problem is a redesign of the distribution system. This would probably be unacceptable by management. The remaining option therefore is to have a series of forecasting models which can improve the degree of accuracy. All of the companies had the ability to manipulate the SES systems to cater for positive or negative trend. None appeared to allow either their computer or their provisioners to use these systems. In fact most argued that their provisioners were not sufficiently trained to operate complex systems. SES whilst not perfect is quite capable of maintaining an acceptable degree of accuracy as long as the weighting is manipulated quickly. There is no appreciable advantage from imposing an alternative system, especially for negative trend. It is probable that a rising trend is best forecast by pure management intervention and from research. Within retailing Divisions such as 3M and Boots new products have appointed managers. Within public bodies it is generally managers who have products!

Throughout, the thesis, has argued against complex systems. To attempt therefore at this stage to introduce highly complex technique such as regression analysis would be incorrect. One of the premises which was repeated throughout Chapters 3, 4 and 5 was that no forecasting system will ever be totally accurate. In order to assess whether there was any improvement by using alternative systems 6 years worth of data was used for those items that fell out of the model as problem cases. The following forecasting methods were used to assess the relevance of the additional effort required:

a. SES.
b. Focus Forecasting.
c. Holts Method.
d. Holts-Winters Method
e. Arithmetic Mean.

In none of the tests was any forecasting model capable of dealing with the erratic demand.

<u>8.4.Service Level for Insignificant Item Headings</u>. The classification allows alternative service level options to be implemented. Stock out of important items,from an operational view, should be avoided wherever possible, even at the cost of economy. Insignificant items however should not attract the same high service level. If the present stocks of inventory can be regarded as excessive this is partly due to the blanket application of formula and policy over the complete inventory. Having identified, even inaccurately,significant and insignificant (with the error biased toward those items classed significant) then the captive customer can be forced to wait before receiving those items that do not prevent him from carrying out his operational task (see Chapter 5 paragraph 5.2 for a fuller development of this hypothesis). Whether or not the forecasting of insignificant items is correct as long as the formula errs towards understocking

this is sufficient. Excess stocks can be easily identified by using policy constraints eg no more than 4xFQD' s total holdings etc.

However the level of stockholding is still artificially raised by maintaining an equivalent service level to that of significant stock. It is therefore argued that having identified the insignificant stock then the safety level should be reduced. The graph below shows the level of saving that can be achieved should this approach be adopted.

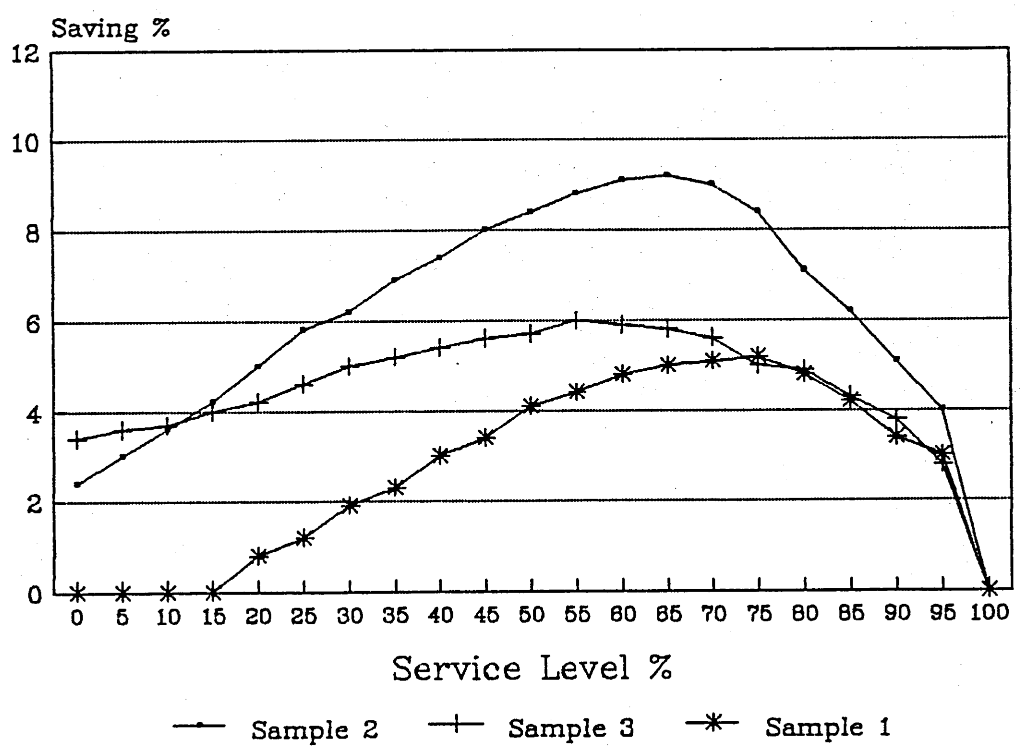


Figure 8-1

8.5 COMPARISONS

Comparisons between inventories should only be made when:

a. Data can be proved accurate.

b. Analysis methods are comparable.

c. The reasons for carrying inventory are similar.

d. The type of inventories are similar regarding:

(1) Product profile.

(2) Size.

(3) Depth of stock.

(4) Population and number of customers.

(5) Demand Profile is equatable.

e. The control mechanism and policy constraints do not diverge significantly.

f. Missions are similar.

g. Stock out risks are similar.

h. Calculations relating to efficiency use the same formula.

i. Incentives for success are the same.

j. Staff technical abilities, training and incentives are similar.

CHAPTER 9. CONCLUSIONS AND FURTHER WORK

9.1 Introduction. Since submitting the thesis the student has reverted from the theoretical pastime of the academic to the real world of inventory control. This chapter not only deals with the hypothesis conclusions but relates the effect of implementation of elements of the thesis to date.

9.2. Forecasting and Inventory Control. The thesis advocated that the classification of inventory would enable greater control of large inventories allowing:

a. Flexibility of systems.

b. Greater automation.

c. Increased application of discrete policy for sub groups.

d. The improved identification of sub groups.

9.3. The significant dependent sub group was the first area singled out for attention. A satellite MRP system has been introduced and reprovisioning for these items is now being undertaken using the Bill of Materials for their parent equipments. This sub section of inventory has a mean leadtime of 24 months. Provisioning has been initiated for 92/93 and 93/94. This system, running in parallel to an SES forecasting model is expected to increase the availability of significant dependent spares to 100% over the next four years.

9.4. The significant independent category, whilst not forecastable to any degree of accuracy is forming the basis for a trial which allows greater automation and flexibility of systems. The recommendations for the trial utilising EDI techniques from secondary through Primary directly to contractor are expected to become operational in November 1990.

9.5. Insignificant items whether dependent or independent have initially been inhibited and their PRF's suppressed. This action in line with the thesis hypothesis has realised significant financial savings which as at 1 April 1990 were recoded as £909,000.

9.6. Differing service level settings for the variable sub divisions of inventory have been presented to Senior Management and ratification is awaited.

9.7. The hypothesis that all inventories contain sub-elements of inventory which do not respond to blanket policy has been accepted and these groups are in the process of identification. The concept of using electronic tags which relate to primal variables is in the staffing chain. The primal variables within the inventory have been identified as:

a. Product characteristics.

b. Lead time.

c. Customer operation and offtake.

d. Demand pattern and offtake.

e. Repair characteristics.

f. Distribution parameters.

9.8. The control of inventory by multiple ABC analysis related to classification has been extrapolated to the complete inventory and recommendation for the reorganisation of provision resources to improve control methods proposed.

9.9. Policy. The process of identifying significant elements of the inventory has not been confined to sub division alone. Inventory Policy as stated in Chapter 3 forms a major part of inventory control. In the process of introducing change to the inventory system the following major policy changes have also been addressed:

a. The forecasting formula used at secondary depots have been amended in line with Primary changes. This action is complete for the major secondary depot and all secondary depots will be amended by 1991.

b. The SPS has been reviewed and changes to the peace time supply methods proposed.

c. Base line data at primary level was found to be corrupt and the process of rectifying this has commenced. It was found that sub division of the inventory was only partially successful until data was credible. The data was believed accurate prior to the attempt to sub divide. The spin-off of sub division in the first instance therefore was greater awareness of the real situation.

d. The communication system to secondary depots was incapable of dealing with demands for significant dependent/independent offtake. This has been reviewed and new systems have already been installed in 2 locations.

9.10. <u>Further Areas for Study</u>. The following areas should be considered for further study:

a. Communication integration.

b. Artificial Intelligence.

9.11. <u>Communication Integration</u>. Electronic Data interchange is still in its infancy. It has been retarded by the proliferation of operating systems and the narrow minded approach of its users. The move to IBM standard operating systems and the gradual definition of standards of data output increase the flow of information. Potentially information could flow from the customer, throughout the logistics organisation and finally to the ultimate supplier. The sub division of inventory allied with electronic tagging will enable this complete flow to be effected without management interference. Management Policy, constraints and conditions, would be targetted against each sub division which could be a few or many hundereds of part numbers. The ultimate goal of such an extrapolotion would be a data communication system which would result in a zero stock inventory.

9.12. Artificial Intelligence. In order to achieve the correct constraints and conditions for a stockless inventory the computer system would be required to select suites of Policy which governed each sub division. Artificial Intelligent systems have the capability to provide this form of Policy which would be amended, updated and controlled by management.

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