DEVELOPMENT OF TWO FORECASTING SYSTEMS AND THE DESIGN OF HARDCOPY INFORMATION DISPLAYS.

A thesis, submitted for consideration for the award of Master of Philosophy,

by Richard Hurdwell
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Development of Two Computerised Forecasting Systems and the Design of Hardcopy Information Displays

SUMMARY

This thesis records work carried out under the auspices of the Interdisciplinary Higher Degrees scheme at the University of Aston-in-Birmingham, at the company of fastener manufacturers Geo. Tucker Eyelet Co. Ltd..

Two main projects at the company are reported. The first being the forecasting of raw material requirements. The need for more accurate forecasting is examined together with the existing materials control systems and the Materials Controller's responsibilities. The flow of information in and out of the materials control department was examined and as a by-product of this investigation a revised method of ordering was suggested and has since been adopted. The company had already established part of a computer system and the author was required to complete the forecasting module.

Two computer "packages" were rejected as unsuitable for this application and a series of FORTRAN programs purpose-written. Only part of the system has been implemented - from which some stock reductions have resulted.

The object of the second company project was to forecast monthly demand for a major group of products, with a 3-month horizon, to aid production control and short term planning. Historical computer records were used to test the suitability of various forecast methods, and a method combining historical and partially known forward orders was incorporated in a regular computer system. This system cannot now be useful until the company rectifies the decreasing accuracy of its Order Processing System, and interim aids are suggested.

An investigation is also reported of the Hardcopy Display of Information, prompted by its effect on system effectiveness. End-uses of information are classified and a wide range of experimental evidence is brought together as a practical guide to display design.

The Development of Two Forecasting Systems and the Design of Hardcopy Information Displays

CONTENTS

PREFACE

I would like to acknowledge the encouragment, assistance and support generously given by a number of individuals and organisations who have made this thesis possible. The work was carried out under the auspices of the Interdisciplinary Higher Degrees Scheme at the University of Aston-in-Birmingham who brought the project and myself together. Geo. Tucker Eyelet Company Limited employed me, providing the problem and paying my salary. The Science Research Council contributed through an Industrial Studentship. Mr. J.B. Kidd was the main supervisor and generously devoted much of his already busy time in discussion with the author, providing invaluable suggestions and encouragement, and also reading chapter drafts. Mr. D. Hale as an associate supervisor enthusiastically helped to initiate the investigation into displays, and on leaving was succeeded by Dr. D. Whittfield who helped enormously by seeking out more references and making useful suggestions for improving the chapter. Dr. C.D. Lewis as the other associate supervisor has offered guidance on forecasting techniques, especially through his excellent books and papers summarising the subject. Dr. D.J. van Rest co-ordinated the supervisors and made useful suggestions to keep the work proceeding in the right direction. Mr. R.P. Newby, Group Management Services Manager at Tuckers, as the industrial supervisor had the foresight to start collecting data for the investigations long before the author began, and then contributed support and direction to the work as it proceeded. Many other people throughout Tuckers spent much time in providing information, advice and computer time. Mr. K.D. Eason of Loughborough University and Dr. Lars Lönnstedt of the Royal College of Forestry (Stockholm) contributed useful comments on drafts of the Displays chapter. Secretarial assistance was provided by the IHD scheme and by Tuckers. I am especially grateful to Mrs. Chantal Purdy who typed the thesis ahead of schedule.

The work reported herin contains some commercially valuable information. Any such data has been disguised without, I hope, destroying its validity.

References have been collated into two separate appendices, the first for the forecasting systems developments and the second specifically for the displays investigation. This has been done to aid those readers interested particularly in the displays aspect to provide them with a (hopefully) useful collection of references on that subject.

R.H.

GENERAL BACKGROUND TO THE PROJECT

The Company

The company in which the project has been implemented is theGeo. Tucker Eyelet Co. Ltd. It is situated in North Birmingham, employs approximately 2,000 people and manufactures more than 150 million products per week.

Tucker is a wholly owned subsidiary of the United Shoe Machinery Corporation (Boston U.S.A.) but retains a high degree of local autonomy. The Corporation consists of four main divisions - Fasteners, Shoe Machinery, Chemicals, and Heavy Machinery.

The Fastener Group, has companies in America, Australia, France, Japan, Germany and Spain. Control of these overseas companies is centred on Tucker, the largest company in the group.

The Products

The main technology of the firm is in the field of small metal pressings - including design of their own manufacturing machinery.

The main products are blind riveting systems, eyelets, and various metal pressings, but there is increasing diversification into other fastening systems - stud welding and also bolting, clamping and screwing fixtures for concrete, wood and plastics.

The Market

The Tucker company's major markets are the vehicle, aircraft, electrical and electronic, domestic appliance, shoe, stationery, construction, leather and light engineering industries.

More than 50% of Tucker's present output is exported through specialised foreign sales agents and other companies within the Corporation.

In the U.K. Tucker sell mainly directly to industry through its national sales organisation, but a proportion of the total (chiefly 'Pop' rivets) is distributed to smaller customers through a nationwide network of stockists.

The Author's Position in the Firm

The author was recruited into the Management Services Department of the Company. This consisted of about eight systems-analysts and computer programmers, plus three O. & M. analysts. There was no O.R. group or analyst in the Company.

The author was the only person using the FORTRAN computer programming language, (the other programmers using the COBOL language for their commercial systems) and as a member of the systems development group, was responsible for design and implementation of his own systems and programs.

Initially responsibility was to the Group Management Services Manager, but this was transferred to the Systems Development Manager. When the latter left the company the former re-assumed the role of Industrial Supervisor; which he still holds, Systems responsibility being with the Development Manager's successor.

The Project

The project was conceived as having two distinct main objectives, both concerned with forecasting.

The first was to complete the analytical part of a system to forecast factory demand for raw materials, and the second to predict future sales.

These investigations are reported in chapter 1 and 2 respectively, together with the results of an investigation into the Hardcopy Display of Information (chapter 3).

CHAPTER 1

RAW MATERIALS-DEMAND FORECASTING & INVENTORY CONTROL

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I N D E X

1.1.0 INTRODUCTION

An investigation is reported of the information flow affecting materials control, and the way in which a computer forecast system could fit into that flow.

A general picture is presented of the materials control 'environment', the materials controller's job, and the steps which had already been taken to set up a forecasting system.

The suitability of a commercial computer package for forecasting was looked into but this was rejected and purpose written forecast and simulation programs were written. During this work the value of graph plots became obvious and a computer routine was written to plot graphs on the Company's lineprinter.

The functions of a program intended to produce forecasts week by week are outlined followed by the reasons why the system has never been adopted. The intended improvements to the manual system are then outlined together with suggestions for further improvements.

1.2.0 GENERAL BACKGROUND

The Company spends approximately £3.5 million anually on raw materials for the manufacture of its various products. The materials are mainly monel alloy, alluminium alloy, steel, brass and copper, in the form of wire, strip or bar.

Many of the production processes require forming by the high speed pressing and punching of small work-pieces. This requires relatively high uniform standards of metalurgical properties and close dimensional tolerances. These quality requirements can cause problems in Raw Materials Control because some metals have to be specially processed by the suppliers for Tuckers' use. This often makes 'off-the-shelf' purchase of materials from alternative suppliers (or fast supply from existing suppliers) difficult or impossible.

Occasionally there may be a large transfer of stock to other overseas factories in the group but the Materials Controller is often notified in advance.

There can be deterioration of metal stocks with extended storage, mainly the rusting of steel and damage to exposed or overstacked items in the smaller, less well organised stores areas. Some organisation of stock on a first-in-stores-out basis is desirable together with more careful use of available space.

Delivery lead times (the time from placing an order to receiving the materials) varies from 4 to 12 weeks depending on material, but can be as much as 60 weeks for some items which must be specially treated after manufacture.

1.3.0. THE RAW MATERIAL FORECASTING PROBLEM

To maintain its share of the market in the face of increasing competition from both rival and subsitute products, the company has realised that they must be able to satisfy customers orders with the least possible delay. An important factor in achieving this is that a steady flow of finished goods must be available. To avoid the cost and space penalties incurred by holding high stocks of finished goods, sufficient raw materials must be available, allowing full flexibility of production to meet changing demands.

Raw material is, however, also subject to similar (if lesser) stock holding penalties and thus it is important to have a good estimate of the likely future demand for raw material.

Senior management felt that there were two problems in this material forecasting area. They wished to lower stocks where possible and they wished to have more confidence in the way the material control department achieved (and could thus be expected to continue achieving) this.

To help solve these problems it was thus necessary to look at the material control function, the way the department worked (including the reasons for lacking confidence in the department), and the methodology employed in making forecasts.

1.4.0 THE RAW MATERIALS CONTROLLER'S JOB

1.4.1 Responsibilities

The prime responsibility of the Materials Controller is to ensure that sufficient material of suitable size and quality is available when required for production. He negotiates delivery schedules and sometimes prices with the suppliers. Although he is not directly responsible for the commercial aspects of the buying function he generally places orders which are later confirmed by the purchase office.

The company buyer is expected to monitor the price of materials to try to ensure that the 'average' price paid over a period is that budgeted for by the senior management. The Materials Controller is however responsible for deciding with which suppliers orders are to be placed.

Having placed the orders he must progress them to ensure punctual delivery, or to be forewarded if delivery will be unavoidably late.

Company metalurgists cut a short sample length from the end of each coil of wire or strip and report any defects to the Materials Controller who is responsible for negotiating the return and/or replacement of such materials and for informing production if this could lead to an unexpected shortage.

The Materials Controller must monitor the levels of all materials stock and regularly report the details to senior management.

1.4.2 Existing Status Recording System

All stock level records are held in a small manually updated 'KARDEX' system in the MC office. Each item of raw material (size and quality within material type) has a card showing the existing stock level. Written notification of withdrawals from stock are delivered, by hand, daily to the Controller who enters them onto the appropriate KARDEX record together with the re-calculated remaining stock figure.

The Materials Controller has thus rapid access to up-to-date stock records. With the cards are kept records of orders not yet delivered, these records also being ammended as soon as delivery is notified. If part of a consignment is found to be of an unusable quality the order record is ammended in red and indicates that part of the stock level shown is not available for production.

1. 4. 3. The Present Materials Forecasting System.

Weekly totals of stores withdrawals are made from the daily flow of data. For all items, apart from very slow movers, a 10 week rolling average is then updated.

i.e. $$\text{Rolling Average} = \frac{\text{Total withdrawals in last 10 periods}}{10}$$

For routine forecasting the assumption is made that the average weekly withdrawals over the next lead time will be equal to the latest value of rolling average. Hence, if F_L is the forecast usage for the next lead time of L weeks:

$$F_L = \text{Rolling Average} \times L$$

The lead time, L, for each item of stock is currently taken as being constant (although the values of lead time for the different stock items are not necessarily equal to each other).

Other information, e.g. about future production targets or expected changes in product demand level, is taken into account by the Materials Controller in ad hoc forecast adjustments.

Preparation of weekly totals and forecasts is done manually with the aid of a simple desk calculator, and the results recorded in the Kardex Records.

Shortcomings.

The present system is unsatisfactory in a number of ways.

Demand 10 weeks ago has an equal effect on the 10 week average as does demand in more recent weeks. This makes the forecast slow to respond to real changes in demand level. The system does not make provision for regular checks of forecast accuracy to alert the controller of problems or demand level changes, nor does it allow for the inclusion of any a-priori information which may be available. To operate the system it is necessary to hold data for each of the last 10 weeks history in a live file, regularly adding the latest weeks data and deleting that for the oldest week. This is a cumbersome clerical task when applied to a number of stock items of material; and the number of operations involved introduces an unnecessarily high risk of human errors.

1.4.4. <u>The Materials Controller's Attitude to his Job.</u>

Below are some observations on factors affecting the Materials Controller and his communications with senior management which may have influenced the effectiveness of his efforts and made management think this was a problem.

The Materials Controller is enthusiastic about introducing more sophisticated techniques and apparatus to improve his forecasting and stock control; techniques about which he is quite well informed. Unfortunately the speed at which he discusses technicalities tends to be too fast for appreciation by the layman and that this rapid-fire method may have made it more difficult for the Controller to get his new ideas approved by the company. Furthermore it seems that his enthusiasm also has some effect on the way he implements his own ideas. Often, having decided upon some improvement to his office system, his thoughts progress quickly to more ambitious extensions, leaving the basic idea unactioned. Another reason for the lack of implementation may be the Controller's apparent pressure of work, the day-to-day administration of his office causing frequent interruptions if he tries to complete any major study.

One of the Materials Controller's long standing suggestions has been that a sophisticated electronic calculating machine be installed in his office so that he could carry out more accurate forecasting and stock control. The fact that such a purchase has never been sanctioned and that no reason, satisfactory to him, has been given does, the author observes, frustrate him in his efforts to improve his existing system.

These feelings have probably become less acute during the last 12 months following the appointment of a more enlightened production manager, but they undoubtedly still exist to some extent.

It would seem that since the areas of stock targets and purchasing are particularly fundamental to the materials controller's job, his lack of formal authority in these areas detracts from his enthusiastic involvement in the job and his consequent attitude to the company. Stock targets are generally set by senior management with changes often being made without regard to the practicalities of implementing the change in the required time period. Purchasing is dealt with by the purchasing office, even though they are not experienced in dealing with raw material suppliers.

1.5.0 INITIAL STATE OF THE FORECASTING PROJECT

When the author started at the company some work had already been carried out preparatory to producing a computerised forecasting system. The company had insisted that the system should be designed for use on its own ICL computer, against the advice of the Materials Controller who had recommended the purchase of a 'desk-top computer' for the task.

The Materials Controller had specified requirements for programs to set up and regularly update a computer file containing 3 years' history of week-by-week stores withdrawal quantities for each stock item. This data would then be used to test, by computer simulation, the accuracy of forecasts by different methods, and for ranges of controlling parameters within these methods. Having established the most accurate forecast method/ parameter for each stock item a regular weekly fore-casting system would be set up to accept data on the latest week's withdrawals; update the demand history file (loosing the oldest week) and to forecast future demand.

When the author started, COBOL programs had been written by the Data Processing department for the file creation, maintenance and regular weekly updating functions, but the forecasting programs had been left pending the arrival of a FORTRAN programmer.

This briefly was the situation when the author commenced the project.

1.6.0 INFORMATION FLOW RELATING TO MC

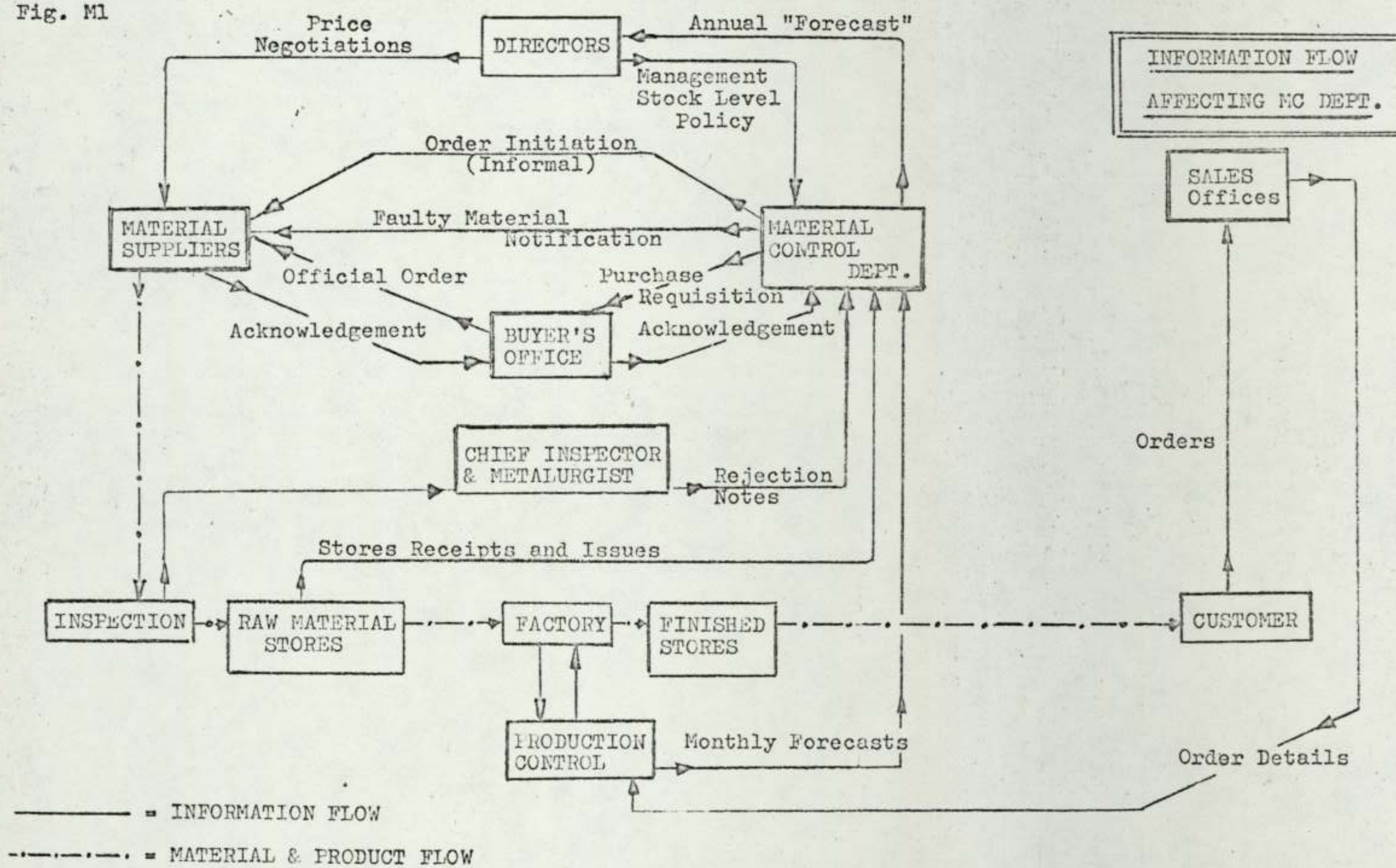
1.6.1 Investigation of the Flow

Concurrent with writing the FORTRAN programs for inclusion in the materials forecasting system the author decided to investigate that part of the flow of information in the company affecting or affected by materials control. This was intended to determine how the forecasting system would best fit into the existing information to fulfil a useful task.

Figure M1 shows the general flow of information - exact details of the mode and frequency being shown on Figs. M2 and M3 which follow it :

Fig.M1

Fig. M1


Price Negotiations
DIRECTORS
Annual "Forecast"
Management Stock Level Policy
INFORMATION FLOW AFFECTING MC DEPT.
Order Initiation (Informal)
MATERIAL SUPPLIERS
Faulty Material Notification
MATERIAL CONTROL DEPT.
SALES Offices
Official Order
Purchase Requisition
Acknowledgement
BUYER'S OFFICE
Acknowledgement
Orders
CHIEF INSPECTOR & METALURGIST
Rejection Notes
Stores Receipts and Issues
INSPECTION
RAW MATERIAL STORES
FACTORY
FINISHED STORES
CUSTOMER
PRODUCTION CONTROL
Monthly Forecasts
Order Details
= INFORMATION FLOW
= MATERIAL & PRODUCT FLOW

PAPERWORK RECEIVED BY MATERIALS CONTROL DEPARTMENT Fig M2

FROM	SUBJECT	TYPE	FREQUENCY	COMMENTS
Rivet Production Office	Material forecast for next 3 months	Typed memo.	Monthly - major items only	Usually received late - used as cross-check against own forecasts
	Forecast for next period (not fixed)	Typed memo.	Irregular	
Eyelet Production Office	Next month's material requirements based on actual orders received at start of month	Typed memo.	Monthly	No breakdown of requirements over time. No account taken of expected incoming orders during the month.
	Requisitions covering minor items	Written memo.	Irregular	
Eyelet & Rivet Sales Managers	New product requirements - forecasts	Written memo.	Irregular	Not always forthcoming.
Export Sales Office	Special overseas orders - can they be made from stock. ?	Verbal	Irregular	e.g. Large quantity of partly finished pressings may be needed for production at an associated overseas factory
'H' Stores (Metal Strip)	Goods received and issue notes.	Handwritten on printed forms.	Daily	Totals checked by Material Control Dept. for transmission to other areas (see 1.2 (i)).
	Weekly totals and stock level summary.	"	Weekly	
Wire Stores	Weight of coils received and issued	Weight tickets (in & out) + Delivery advice notes	Forwarded Weekly	Material Control Dept. computes running stock levels.

PAPERWORK RECEIVED BY MATERIALS CONTROL DEPARTMENT (cont'd) Fig M2 cont..

FROM	SUBJECT	TYPE	FREQUENCY	COMMENTS
Factory 4 Stores	Goods Received and Issue Notes	Handwritten on printed forms	Weekly	Material Control Dept. computes stock levels
Metal Inspector and Metallurgist	Metal Rejection Notes	Handwritten on printed forms	Irregular	Material Controller has responsibility for negotiating replacement/repayment with suppliers.
Buyer's Office	Copy of order sent to supplier	Bottom copy of form filled in by typist	As orders placed	Material Controller checks quantity ordered
Buyer's Office	Supplier's acknowledgement of order	Supplier's form	As received	
Directors	Directives on overall management policy on (maximum) stock levels and 'service' levels expected.	Memos.	Intermittent	Maximum stock levels set according to firm's liquidity rather than on scientifically calculated values.

PAPERWORK OUTGOING FROM MATERIALS CONTROL DEPARTMENT   Fig M3

TO	SUBJECT	TYPE	FREQUENCY	COMMENTS
Directors and Cost Office	Physical stock level reports	Handwritten on printed forms	Weekly	Rapid reaction from Directors if stock rises above their specified levels
Directors and Cost Office	Total monetary value of stocks	Handwritten on printed forms	Monthly	Computed and compiled by the Materials Control Department.
Buyer's Office	"Purchase Requisition" for order quantities required	Handwritten on printed forms	As required	Initiation of order often made from Materials Control Department by 'phone or supplier's representative calling.
Suppliers	Delivery schedules	Typed forms	Monthly	
Suppliers	Faulty material notification	Letter, telephone, or during rep's. call	As required	Mode of communication depends on urgency and extent of faults

1.6.2 Incorporating the Forecast System

There seemed no reason for any major restructure of the Materials Control Function since its activities went far behond those to be provided by the computer system.

Thus, it was recommended that the Materials Control Department be retained, in its existing form. Most of the information flow in the system was deemed to be necessary to the Materials Control Department's functioning and should be maintained.

The basic computer system should, consequently, be incorporated into the Materials Control Department's clerical activity as an aid to, rather than an essential link in, the system. Other parts of the system would remain substantially unaffected except to make the form of information presentation more compatible with the revised needs of the Materials Control Department.

Input to the Computer

The mathematical analysis required two types of information for each material type, size and quality (i.e. each item of stock). Firstly basic details were required of the forecasting and re-order methods which had been pre-chosen for each item, together with all the necessary parameter values for the chosen analysis. These details would be permanently stored on magnetic tape and would be updated, as and when required, by instruction from the Materials Control Department, on new forms designed for the purpose. Secondly, the weekly total of stores issues and receipts of that item were required.

The flow of weekly stores issues and receipts was examined to minimise potential errors and unnecessary clerical effort when preparing the computer input.

Details of stores issues and receipts arrive daily from the various stores locations. In each case the weekly totals are computed in the Materials Control Department. A cross-check, in the case of Strip Metal Stores, is made by comparison with the total as calculated by stores clerical staff.

In other cases totals are sent from Materials Control back to the stores concerned for their approval. This second system is essentially subjective (there being insufficient staff in these areas to complete more clerical activity) but it works reasonably in practice.

The alternatives were thus :-

(a) To make each stores area responsible for producing its weekly totals on a form which (after checking by Materials Control Department and addition of a * forecasting validity key) can be sent directly for computer input preparation.

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* Forecasting validity key indicates if that week's demand (withdrawals) is valid for the forecasting techniques used or whether, by virtue of management intervention, stockouts or production hold-ups, it is invalid.

(b) Leave unchanged the present method for stores notifying Materials Control of stock movement and provide a new form for Materials Control to complete for computer input preparation. A bottom copy of this form could act as a paper record for retention by Materials Control, if required.

Since it was deemed necessary for Materials Control to compute their own totals for checking purposes, the latter method would be less disruptive and involve least extra clerical effort. It did not seem reasonable, in the interests of accuracy, to eliminate this cross-checking procedure. Also, in working through the information the Material Controller probably derives some "soft" (or subjective) information about the state of the material demand which will help not only in a general appreciation of the situation, but will assist more specific decisions such as choosing the validity key.

Output from the Computer

The weekly computer output would be sent only to the Materials Control Department containing, as it would initially, only data which would aid them in carrying out their task. If the system proved reliable it would be given increasing responsibility for setting inventory levels and order quantities with minimum human intervention. (The system, being self-monitoring, would indicate those items which need manual investigation, thus freeing material control time from 'routine' computations to deal with these exceptions).

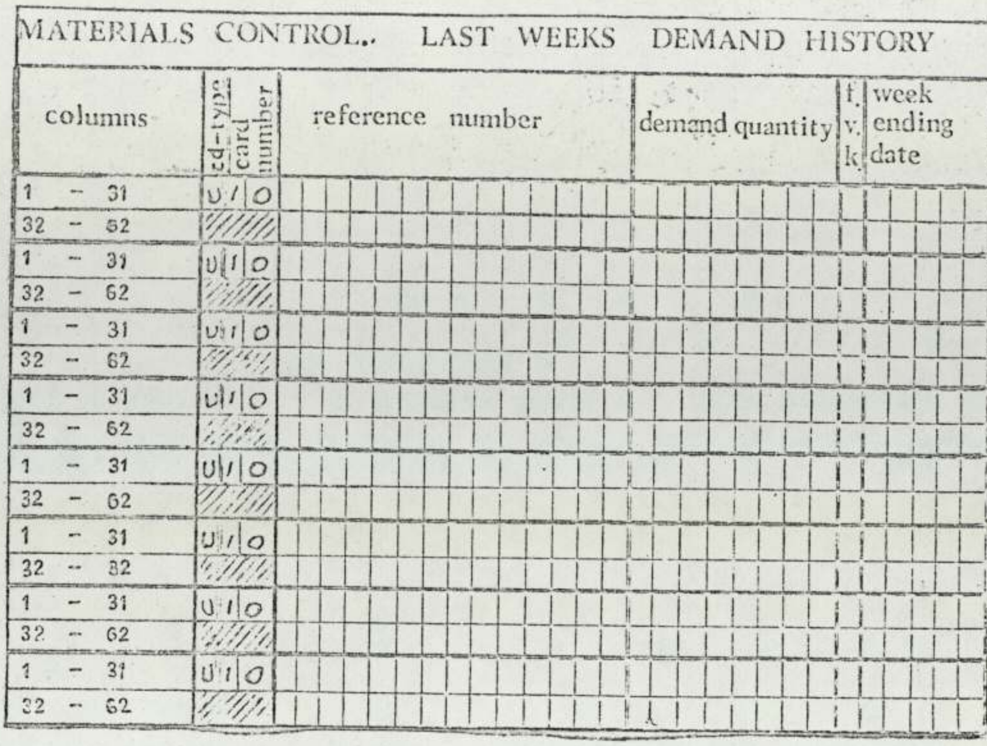
1.6.3 Observations from the Information Study

Whilst investigating the information flow several observations were made and were followed up in later work.

The first was the way the layout of a computer input document could affect punching accuracy. An example of the document, which was designed in the company's data processing department, is shown on Figure M4. Examples of this document, filled in with real values, were sent for punching at three different places; the firm's own card punching section, the University's punching service and a commercial bureau. Interpretations of the meaning (and hence the way the cards were punched) was different in each case, and none of them were the way the designer had intended. This highlighted a general problem which had obvious ramifications in all applications where information is to be passed from one person to another by purely visual communication - namely the effect which information content and display has on the way its recipient will interpret and use it.

The realisation of this problem area prompted the author to carry out a more detailed investigation into display design and this is reported in Chapter 3.

A second observation was the usefulness of drawing the information flow diagram (figure M1) with departmental functions at the nodes. By considering the potential and actual information generated by each department and comparing this with the potential needs of all the other departments it was easy to identify weaknesses in the existing flow. The particular weakness noted was the lack of a formal communication channel to the Materials



MATERIALS CONTROL.. LAST WEEKS DEMAND HISTORY

columns	card-type	card number	reference number	demand quantity	f.v.k	week ending date
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						
1 – 31	U /	0				
32 – 62						

Fig. M4 - EXAMPLE OF A MISINTERPRETED PUNCH DOCUMENT

The programmer/form designer had intended two part numbers to appear on each card, starting in cols. 3 and 32, but had arranged them vertically for ease of filling in. Some punch girls punched one per card, with alternate cards having 'U1O' in cols. 1-3 and cols. 1-3 blank on the other cards. Some punched alternate cards with every second card being blank to col. 31, the part number starting in col. 32, and some punched two per card but started the second part number in col. 35, assuming the blanks below each 'U1O' to mean cols. 32-34 blank !

Control department from the Sales Offices, who were the first to receive new orders and could therefore be expected to be the most important potential source of the company's forecasting knowledge.

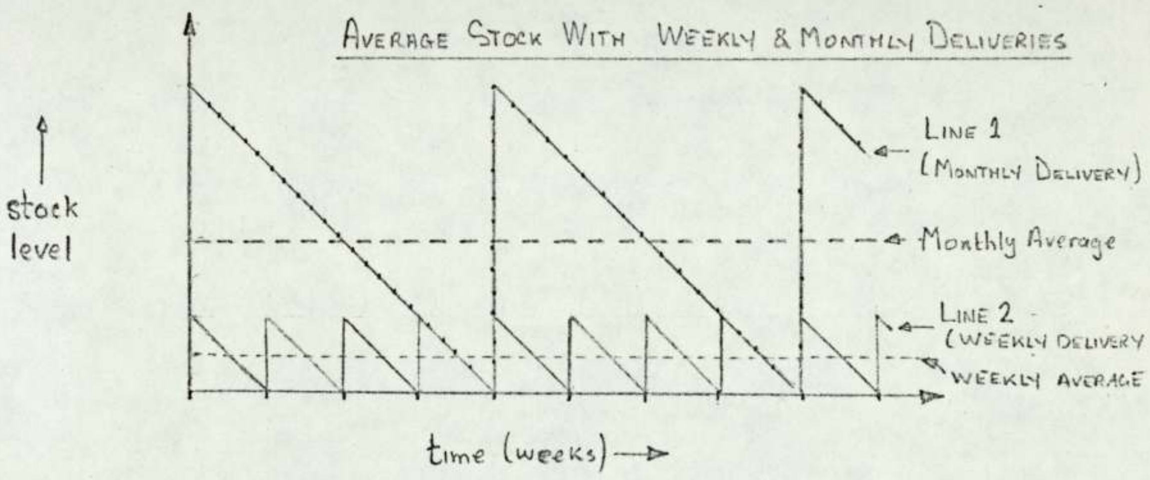
Further investigation showed that an informal system of sorts did exist, with certain sales staff notifying the Materials Control if particularly large individual orders were received. The author suggests that it might often be the case that where informal information systems exist there might well be a deficiency in the formalised system.

It is also suggested that the departmental 'Input/ Output' analysis mentioned above could be a useful tool for systematically identifying such deficient areas - even to the extent of computerising the comparison, in the case of very large organisations or when applying it to the interaction between individual workers or work groups in a complex work situation.

1.7.0 IMPROVEMENTS IN THE METHOD OF ORDERING.

For high volume, regularly used, items of raw material, stock replenishment orders were (at the time the project started) placed once per month, each order consisting of a schedule of 4 weekly deliveries, the first to be made one lead time ahead. Suppliers did not generally allow significant changes or cancellations to these orders once placed.

With regular re-ordering the average stock is equal to half the order quantity - assuming that delivery of the entire order is made at one time.
Re-ordering weekly instead of monthly would thus divide the average stock level by four (lines 1 and 2 below).



In terms of average stock the company's original policy of monthly re-ordering a weekly delivery schedule has the same result as weekly re-ordering. However there is another way in which weekly re-ordering can help reduce stock level. A monthly schedule must allow for unexpected changes in demand level occurring shortly after the order is placed. If orders are placed weekly, corrective adjustments can be made to the next week's order in response to demand changes.

Reducing the period between orders thus makes possible a calculated stock target reduction. The minimum reasonable re-order period was one week, since demand monitoring for shorter periods would not be representative of true demand level.

The Materials Controller agreed to try weekly re-ordering, and the suppliers also accepted the proposition. It is now the normal method of re-ordering several high volume items and since it has been successful, it will in time be extended to other items.

1.8.0 POSSIBLE USE OF COMPUTER PACKAGE

Before proceeding to write computer programs to find the optimum forecasting method the author looked into the possibility of using a standard software 'package' to serve the same function. The forecasting package available for use on the company's computer was called SCAN-1. * Tucker's main requirements for such a package are examined below, and compared with the facilities available from SCAN.

1.8.1 Requirements for Materials Control

The main requirements of the forecast method appraisal programs are as follows:

Based initially on the past pattern of material usage by the factory, forecasts are to be made of future usage rates, with material stock levels adjusted accordingly. Replenishment orders must be placed several weeks in advance of the required delivery date, this 'delay' period being called the delivery lead time.

For materials which are in constant use but at widely fluctuating demand levels, it is often desirable to re-forecast and re-order frequently, especially (as is presently the case with MONEL) when order cancellations cannot be made.

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*SCAN System 2 is a simplified version of '1' for smaller machines and System 3 is for disk machines. The latter has more options than 'SCAN'1 and uses slightly more powerful analysis techniques - otherwise it is basically similar to 'SCAN' 1.

Hence, for example, if the delivery lead time was 8 weeks it would be necessary to forecast the demand expected in the next 8 weeks and then deduct the orders already placed for delivery in the first 7 weeks of that period. (These figures might be 9 and 8 weeks respectively depending on the re-ordering criteria employed).

The requirements for Materials Control are then, to accurately forecast future demand in order to make replacement orders. Another necessary requirement is that the Materials Control Department accept the forecasts and can use them with some confidence.

1.8.2 Functions of SCAN

Demand Forecasting

Historical demand data is read from cards and used to create a magnetic tape called 'STATISTICAL' from which information is taken during analysis.

Firstly, 'SCAN' ensures that demand has occurred sufficiently frequently to be meaningfully forecast (i.e. very 'slow-movers' are discounted or the interval between forecasts extended).

The forecasting technique used in SCAN-1 is the Box-Jenkins Prediction Model. This is similar to the widely used techniques of exponential smoothing but allows a wider range of forecasting parameters to be used.

The 'parameters' used in this forecasting technique are constants in the forecast equations which determine how responsive the forecast will be in following changes of demand. Too great a response will cause wild fluctuations in the forecasts following small natural fluctuations in demand; whereas too sluggish response will be very slow to recognise real changes in the level of demand.

'SCAN' estimates the values of these parameters which will give the least error in forecasting (retrospectively) the historical demand data. The general criteria for these best (or optimum) parameters is that the sum of squared errors in forecasting <u>one period ahead</u> should be minimised. It also analyses the serial correlation coefficient of the data to see if there are any significant trends (overall increases or decreases) or regular repeated cyclical variations in demand.

Next 'SCAN' runs a form of simulation of the data to determine more precisely the best values of the forecasting parameters and also to quantify the trends and cyclic variations.

The results of the above analyses are stored on the 'STATISTICAL' tape along with the demand data and can be used to forecast (unknown) future demand.

<u>Inventory Control Function</u>

'SCAN' allows for two forms of re-order pattern, cyclical re-ordering and random re-ordering. Cyclical re-ordering is when orders are placed at regular predefined intervals of time; random re-ordering is where stock levels are periodially reviewed and an order is placed only on those occasions when the stock level is below some predetermined level.

The programs evaluate a stock target over a period on the basis of the forecast demand in that period plus an allowance for the likely magnitude of possible errors in the forecast.

This latter allowance (the safety stock) employs a concept of 'Customer Service' based on the probability of running out of stock. It has been shown (R.G. Brown (1959)) that this can lead to a falsely high value of stock.

To make any use of prior knowledge about likely significant changes in demand the average demand and trends in the analysis must be manually re-calculated and the STATISTICAL tape amended accordingly. Allowance for prior knowledge is not provided as a routine procedure.

Simulation Function

This provides the facility of simulating, in a short time, what would have happened over a past period if the SCAN forecasting and inventory control routines had been employed during this period. It uses the same historical data used in developing the optimum parameters, together with those parameters and cyclical factors.

The re-order policy to be adopted is specified and the simulation program prints out details of the forecasts it is making, orders being placed and current stock level. At the end of the simulation the means and standard deviations of forecast error and stock level are printed out.

In this way the effect of changes in various policies can be evaluated and compared (by successive simulation runs).

It is feelt that these simulation printouts are a useful aid in gaining acceptance for the system from interested potential users.

1.8.3 Suitability of SCAN

One difficulty which arises in using 'SCAN' is that it chooses forecasting parameters which minimise forecasting errors only when forecasting one period ahead. In the case of materials control this forecast will be made weekly for important items. Lead times however are (typically) in the order of 8 weeks. The author has shown that the optimum parameters for forecasting one week ahead are far from optimum when used to forecast 8 weeks ahead. This is inconsistent with 'SCAN''s inventory control function which can make regular forecasts for a number of weeks ahead, even though it has not computed the optimum parameters for this case.

The part of 'SCAN' which could be usefully employed is the facility for statistically identifying and calculating seasonal patterns in the demand data. Total lead time demands for successive lead times are used as input DATA for 'SCAN' to carry out these statistical tests.

The inventory control function in 'SCAN' could be used in the Materials Control area but has the following shortcomings.

(i) It includes no routine procedure for employing any prior knowledge of future demand changes (hand calculations of the various factors would have to be made and the files updated to re-initialise the system).

(ii) There is no simple facility for indicating that certain demand figures should be ignored for forecasting purposes, although they must be included in the stock records. (This situation is not uncommon in the Materials Control area at Tucker since very large 'one off' withdrawals may be made for despatch to other factories - the local factory demand pattern has not changed but would be interpreted as such by the Box-Jenkins forecast model used in SCAN *.)

1.8.4 IBM'S RETAIL 'IMPACT' PACKAGE

At the time of this investigation it was possible that the company's ICL computer would be replaced by an IBM machine, when the IBM package 'IMPACT' would become available. The forecasting function of the package was briefly appraised and compared with 'SCAN'.

No major disadvantages (of 'SCAN') were immediately obvious in the 'IMPACT' package, but the following advantages were noted:-

(i) IMPACT allows for a 'calendar' of selling days in each period and will make the appropriate weighting in the forecasts for sales during that period (this would have been a manual task is 'SCAN' was used).

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* SCAN System 3 uses a lagged adaptive forecast and would perform better in these conditions.

(ii) IMPACT's main forecasting technique uses a form of adaptive smoothing (with trend) which may make the optimality of lead time forecast parameters less imperative than in 'SCAN' but which will not necessarily give more accurate forecasts (depending on the demand pattern for each item).

(iii) 'IMPACT' produces (on request) a graphical output showing forecasts against actual demand - an aspect which is important to user acceptance.

(iv) The calculations of 'Customer Service' are based on the percentage of orders that may be lost during stockouts rather than probability of stockout. This is a more meaningful criteria in many retail level situations than that used in 'SCAN'. However, at internal factory level it still may not be sufficiently meaningful.

Conclusions

It was decided that although SCAN could be utilised it would need some alteration to fit Tuckers' requirements and that it would probably be as easy to produce a dedicated 'in-house' system to carry out the fuction.

The company subsequently decided to retain its I.C.L. equipment and thus IMPACT is not available.

1.9.0 OPTIMUM FORECAST METHOD - COMPUTER PROGRAM

Optimum forecasting parameters for some forecast methods can be (approximately) established analytically, but the analysis required is different for different methods, and for some methods could be very complex.

Determination of optimum forecast methods by simulation is more flexible, and it is easier to gain acceptance of the results. This involves a large number of repetitions of the basic forecast arithmetic, which computers are particularly suited to handling. Thus it was decided to write, in the FORTRAN language, a forecast optimising program broadly along the lines already specified by the Materials Controller.

Since this was the author's first major excursion into programming and since it was a moderately involved program this took some time. A listing of the program (including modifications made for later sales forecasts) appears in Appendix C.

1.9.1 Main Program Functions

The program first had to read a magnetic tape (created by the series of COBOL programs already mentioned). For each stock item the tape would contain details of the last 150 weeks' stores withdrawal quantities, each week's total having a 'forecasting validity key' to indicate whether it should be included in the forecasts. (Non-included weeks would be 'short' production weeks, weeks where large quantities had been transferred to another company or where management intervention had artificially affected the figures).

These then had to be compounded into the demand in successive lead times, taken week by week. Thus, for example, if weeks were numbered 1,2,3 ... and the lead time = 5 weeks then the first lead time demand would be the sum of weeks 1 to 5, the second lead time weeks 2 to 6 and so on.

From the weekly figures would be computed smoothed averages and trends and hence lead time forecasts. The three methods initially included in the program are

(1) Simple Exponential Smoothing

(2) Brown's Linear Additive Trend Method

(3) Trigg's Adaptive Smoothing Method

(Details of these forecast methods appear in 1.9.2 below)

Forecasts would be compared with the actual lead time demands to establish the forecast accuracy.

Each forecast method would be simulated using a range of smoothing constants with the sum of squared forecasting errors (SSE) being recorded for each run. The method and associated smoothing constants which give the least SSE being chosen as likely to give the most accurate forecasts in the future. This solution is of course only optimal in terms of the combinations tried.

1.9.2 Forecasting Methods

The three forecasting methods tested by the program were as follows:

Exponential Smoothing

This widely adopted method uses an exponentially weighted average of past events as its forecast. The weighting gives decreasing importance to data as it becomes older (and thus less indicative of the current/future situation) and this makes the method more realistic than the simple average of a given number of periods off history which gives equal weighting to events many periods ago as to more recent ones. Another advantage of the smoothed forecast is that it does not require past periods' data to be held, but only the value of the smoothed average calculated last period.

The formula for calculating an exponentially smoothed average of demand is as follows:

$$^{*}\quad f_{t+1} = \alpha . d_t + (1-\alpha) . f_t$$

where f_{t+1} = forecast for next period

f_t = forecast made last time

d_t = demand during last period

α = a constant in the range 0-1.0

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* Subscripts indicate time period of associated value

i.e. t = last period (just ended)

t+1 = next period (just starting)

The value of α used is usually in the range 0.05 to 0.3, the higher the value used decreasing the 'average age' of the data affecting the forecast and thereby increasing its sensitivity to changes in demand level. Lewis (1970 a) notes that if a value of above 0.3 is needed to increase forecast accuracy then it is likely that the average level of demand is not stationary and that other forecast methods would be more suitable.

Linear Additive Trend

A pattern of demand which often exists is a contuinous trend of increase or decrease in the average value of demand. If a forecast method such as exponential smoothing is applied then the forecast will always lag the actual trend occurring since it can only attempt to catch up with the latest actual value and contains no method of predicting that the actual level will continue to change in the same direction.

There are many patterns of trend which can occur, either separately or imposed on each other, depending on the factors causing the change. The simplest is a linear additive trend where the demand increases by the same amount during each successive period (eg. 100, 105, 110, 115 ...). Other possible trends are a simple linear proportionate increase during each period (eg. 5% increase per period ...100, 105, 110.25 ...) or a more complex rate of growth such as quadratic or exponential. Superimposed on any of these patterns will normally be an element of scatter or 'noise' which normally occurs in real situations.

The LINEAR ADDITIVE TREND method was included in the forecast optimising program as a first step to checking if trends existed which could be forecast. Further trend methods were not tried on the data as the linear method showed no evidence of trends existing.

The method used is due to Brown (1962) and is computed to give the minimum discounted sum of squared errors, which (he implies) is a way of minimising the maximum error. The method is summarised by Lewis (1970- a):

- where f_t and d_t are already defined

and β is the discounting factor

the forecast error $e_t = d_t - f_t$

the trend component $g_t = g_{t-1} + (1-\beta)^2.e_t$

and the stationary component $s_t = s_{t-1} + g_{t-1} + (1-\beta)^2.e_t$

then the forecast for T periods ahead

$$= f_{t+T} = s_t + g_t .T$$

Lewis recommends that a value of $\beta = 0.8$ be used.

Trigg's Adaptive Smoothing (& Monitoring)

As previously pointed out simple exponential smoothing is not suited to situations where demand is subject to rapid and significant changes in level (i.e. 'non-stationary'). This is because the smoothing constant used is generally less than 0.3 and thus at least the last 5 to 6 periods of history significantly affect the forecast.

To overcome this Trigg and Leach (1967) suggested that instead of using a fixed smoothing constant its value could be varied to make the forecast more responsive following significant changes, and less responsive during periods of more constant demand. They monitored the exponentially smoothed average of forecast errors and also the smoothed average of <u>absolute</u> forecast errors (i.e. where only the magnitude and not the sign of the error is included). This latter value is often known as the Mean Absolute Deviation (MAD). The ratio of these two values lies in the range ± 1 and is often referred to as Trigg's Tracking Signal (T) and was first derived by Trigg (1964) from a method of Brown's (1962) as a way of automatically monitoring forecast accuracy.

The absolute value of T ($|T|$) is used in place of the normal exponential smoothing constant in Trigg's Adaptive forecast method. When the demand level changes, the forecast error and also $|T|$ increase, thus making the forecast respond more quickly to the demand change. When demand settles to its new level $|T|$ falls and the forecasts become less sensitive to spurious variations in demand.

Formulae involved in Trigg's Adaptive forecast Method are as follows:

where d, f, e are as previously defined

and $| \; |$ indicates the positive magnitude (or modulus) of the value it encloses

Smoothed Absolute Error $MAD_t = \alpha . |e_t| + (1-\alpha) \, MAD_{t-1}$

Smoothed Error $S_t = \alpha . e_t + (1-\alpha) \, S_{t-1}$

Then <u>Trigg's Tracking Signal</u>

$$= T_t = \frac{S_t}{MAD_t}$$

<u>The adaptive forecast is then</u>

$$f_{t+1} = |T_t| \quad d_t + (1 - |T_t|) \quad f_t$$

Shone (1967) pointed out that the Trigg and Leach method will over respond to an isolated impulse demand where the demand immediately returns to its former level. Thus he suggests the use of the tracking signal calculated at the last period for the smoothing constant in this period's forecast.

The formula for this Lagged Adaptive Forecast is thus:

$$f_{t+1} = |T_{t-1}| \cdot d_t + (1 - |T_{t-1}|) \cdot f_t$$

1.9.3 Program Development Problems

Two factors increased the time taken to prepare the forecast optimising program.

The first was the author's inexperience in the techniques of programming; in particular the technique of setting out a detailed flow chart before coding.

In the light of subsequent programming experience the author realises the great power of using a visual flow chart display to overcome conceptual difficulties in designing complex programs.

A second time consuming factor was the 'turn-round time' of jobs sent to be run on the company's computer. Delays of 7-10 days were not uncommon, due it seemed to lack of control and organisation by the computer controller. It is observed then (and on subsequent occasions when 'turnround' has been very slow) that morale amongst the programmers would fall considerably.

Having got the program 'clean-listed' (i.e. interpreted without errors into machine instructions by the compiler program) it was ready to test. Test data had already been prepared by which an input tape could be produced using the existing COBOL programs. At this point two factors were discovered. The data file creation programs did not work properly and the layout of the records on the magnetic tape was not compatible with that required by FORTRAN.

The programmer who had written the COBOL file creation programs had since left the company and after the programs had been examined by another programmer -

the Data Processing Manager decided that they should all be re-written.

To make the file layouts compatible with the ICL version of FORTRAN two changes were made. - The format of each record on the file is split into 'words' consisting of 4 characters each. The first word indicates the number of words held in each record and this word is common to both COBOL and FORTRAN. The second word in FORTRAN can be used (if required) to control off-line printing from that file, and all subsequent words contain alpha-numeric information. COBOL normally starts <u>its</u> data in the second word, and data in this word will not therefore be recognised as such by FORTRAN - hence the COBOL programs were written to insert a blank word in that position. The second addition was for the COBOL program to write a dummy record at the end of the file in a pre-defined form (a dummy part No. of ZZZZZZ was used) since FORTRAN can not recognise the standard ICL "end-of-file" marker as can COBOL. The FORTRAN programs then included a test on each part number read to check for end-of-file.

In order to test the FORTRAN programs the card source pack was re-produced and one pack converted to accept the weekly history data direct from punched cards. Retrospectively it would have been far better to have included in the first source pack the <u>option</u> of either card or tape input. Having two versions meant that the tape version had to be updated with exactly the same developments as were found necessary in the card version, which was tedious and did not guarantee that the tape version would work.

Also at this time three other FORTRAN programs were written by the author, a forecast program for the regular system, a graph plotting routine and a stock level simulation program.

1.10.0 STOCK LEVEL SIMULATION PROGRAM

The essential reason for forecasting materials demand is to establish what replenishment orders to place, taking into consideration existing stocks and orders already due for delivery. Thus it is not sufficient to just establish the most accurate forecasts possible but it is necessary to determine a target stock level which will give acceptable safeguard against running out of stock when actual demand has been higher than forecast.

The existing re-order method for large usage items was to forecast demand over the following lead time; add the buffer stock target value (thus aiming to cover demand leaving the buffer stock intact); and subtract both existing stocks and orders already due for delivery during the lead time.

A cyclical re-ordering policy was adopted (i.e. orders placed at regular intervals of time) with the constant review period (i.e. time between placing orders) of one week. Using this system the quantity ordered must allow not only for unexpectedly high demand occurring during the delivery lead time, but also high demand during the next review period, since no corrective action can be taken until the next review. Thus the period of 'risk' is the lead time (L) plus the review period (R).

The conventional method of considering safety stock is based upon the likely magnitude of demand exceeding the average which can be determined from the standard deviation of weekly (σd) demand. Allowing a buffer stock of one standard deviation would give a probability of stockout occurring of 15.9%, whereas allowing a value of two standard deviations reduces that probability to 2.3%. The multiplying factor is known as the standard normal deviate (k) and values of the probability for different k values can be found in tables of the normal distribution, an extract of which appears in appendix E. Thus the safety stock = $k.\sigma d\ (R + \bar{L})$ (Lewis (1970b)) where σd = Standard deviation of demand per week.

R = Review period (1 week).

$\bar{L}$ = Mean lead time.

k = Normal standard deviate.

Where forecasts are made by methods other than the simple average the value of the standard deviation of errors about the forecast (σe) replaces the standard deviation of demand about its average. The safety stock value is thus $= k \sigma e \ (R + \bar{L})$

where σe = standard Deviation of forecasting weekly demand.

The Materials Controller had found that delivery lead time for each of the major items was very nearly constant (although the lead times for the items were not neccessarily equal to each other). The assumption of constant lead times was thus made in the programs.

However, it may be difficult to get 'lay' users to accept the validity of this analytical technique, and there are in any case many instances where its assumptions would not be valid.

Consequently it was decided to write a simulation program. This would use the best forecast method/ parameters already found and apply the simple re-order policy outlined previously to the simulated re-ordering of material. The model would be subject to realistic constraints of minimum order quantity and increments of order size.

By monitoring the stock level for each run - with its specified buffer stock target - statistics can be readily obtained about the number and degree of any stockouts which occur and the average value of stock held over the period.

The Material Controller can then try various values of buffer stock (perhaps calculated analytically in the first instance); see the resultant protection against stockout provided, and also find the sensitivity of the results to changes in target levels or order quantity constraints.

Having established a suitable combination of forecast and buffer stock target for each item, the Material Controller can then present a case to higher management (if one is required) for the adoption of these targets. The author feels that the simulation printout showing week by week forecasts; actual demands; orders placed and consequent stock levels should be readily understood by the 'lay' man since it is a representation of real states. Also a graphical output of the stock level would enhance understanding and acceptance of the results.

1.11.0 GRAPH PLOTTING

1.11.1 The Usefulness of a Graph

A column of figures showing week by week demand, with an adjacent column showing forecasts for that demand, needs close scrutiny to identify demand patterns or to observe how well the forecasts predict that demand pattern. The human observer must compare all pairs of adjacent values to establish the direction (positive or negative) and magnitude of differences and build each observation into an overall mental picture of all the observations. This can require considerable mental agility if the pattern is complex or if there are several columns of different forecasts to be compared with the 'actual' column. Furthermore details of the pattern may not be remembered easily and the figures may have to be scrutinised again, each time they are considered.

Statistical analysis of the columns yielding means, standard deviations, sums of squared errors, distributions etc. can be very useful guides in such cases.

However, there seemed to be a great deal of useful subjective information that a manager (e.g. the Materials Controller) can glean from visualising underlying patterns in the data he is handling. This may perhaps prompt some previously untried statistical analysis (e.g. if a seasonal trend is now suspected where none had been before).

Simple graphical presentation of the data can, in the author's observation, enable the pattern identification to be made more readily. Indeed it may be the only way he can be bothered to look for a pattern.

The graph represents the 'mental picture' which the observer builds himself if he only has a table of values, and thus the graph output short-circuits part of his task. He will quickly be able to pick up his thoughts from this point - or refer back to it - without resort to scrutinising the tables again to refresh his memory.

1.11.2 A computer plotting routine for line-printer

Prompted by the observations above the author decided to write a FORTRAN routine to plot graphs from either data on punched cards or on the materials DEMAND-HISTORY file.

The company did not possess a graph plotter, and were unlikely at that stage to purchase one. Hence the output device had to be the standard ICL 120 character line-printer which was already installed.

This apparently simple routine posed two interesting problems. The first was how to manipulate FORTRAN to plot single points at the appropriate distance across the page. This was achieved by setting up a series of 101 blank character fields, each of one character long, and naming each of them as part of a subscripted array, from 1 to 101. The value to be plotted would be re-valued in the range 0-100, according to the scale chosen for the ordinate axis. (This of course leads to a degree of unavoidable approximation but the user would be able to refer to the original table for exact values if required). The corresponding array element (element 1 for value zero, 2 for one and so on) would then have a character or symbol transferred to it and the entire array printed across the page. The appropriate element would be set as blank again before moving on to the next point.

If a number of points must be plotted on the same line (for instance one actual plus one or more forecasts) then the routine would simply be repeated for each value but printed one at a time on the same line with different symbols.

The second problem was that of the scales of the axes. It was decided to plot the independent variable (time) lengthwise on the page. Thus any number of time periods (including the 150 on the materials DEMAND-HISTORY file) could be plotted by continuing from one page to the next. (The maximum number on one page is 66.)

On the ordinate axis appeared the demand value. It was convenient to use 100 of the 120 available character spaces for the full scale, leaving the remainder for data and an axis line. For any given range of values to be displayed it is desirable to fill as much of the height of the graph as possible to accentuate differences in the values of the points plotted. To avoid giving a false impression of relative magnitude a linear scale was chosen with its axis always starting at zero.

The author decided on three possible scale markings to use (depending on which gave the greatest spread of values to be plotted). These were 0 →10, by labelled increments of 0.5; 0 →5 by increments of 0.25 and 0 →2 by increments of 0.1. One hundred unlabelled single increments are indicated by a line of + symbols which also serves to indicate the position of the axis.

The analysis part of the routine thus had to test every value to be plotted to find the highest. It then reduced that value by factors of 10 until the nearest integer came within the range 0 →10. The choice of 0 →2, 0→5 or 0 →10 scales was then made by finding which was the highest scale to include that value. Next to the ordinate axis would be printed the appropriate power of 10 by which the scaled values should be multiplied. E.g. the value 3,592,000 would be plotted as 3.6 on the 0 →5 scale, with a multiplier of $x10^6$ indicated.

Since the routine plots only single points, and if these points do not lie close together (as they would with the plot of a smooth curve) it is necessary to manually join the points by a line. The routine does however relieve the main tedium, that of plotting the points through which the line must be drawn.

Figure M5 shows an example of a graph generated by lineprinter, showing the lead time demand for an item of raw material.

1.11.3 <u>Extensions to the use of the Plotting Routine</u>

The original routine as developed exists as a single dedicated program which can accept data from either punched cards or from a suitably organised magnetic tape file - perhaps output from another analysis program.

It was however straighforward to incorporate the routine into the optimum forecast method program as already described. Actual demand figures are signified by the symbol '*' and the best forecasts of that demand by each of the 3 methods shown by the symbols 1, 2 and 3. There is some advantage in joining the series of similar symbols by lines of different colours (see section 3.7.2)

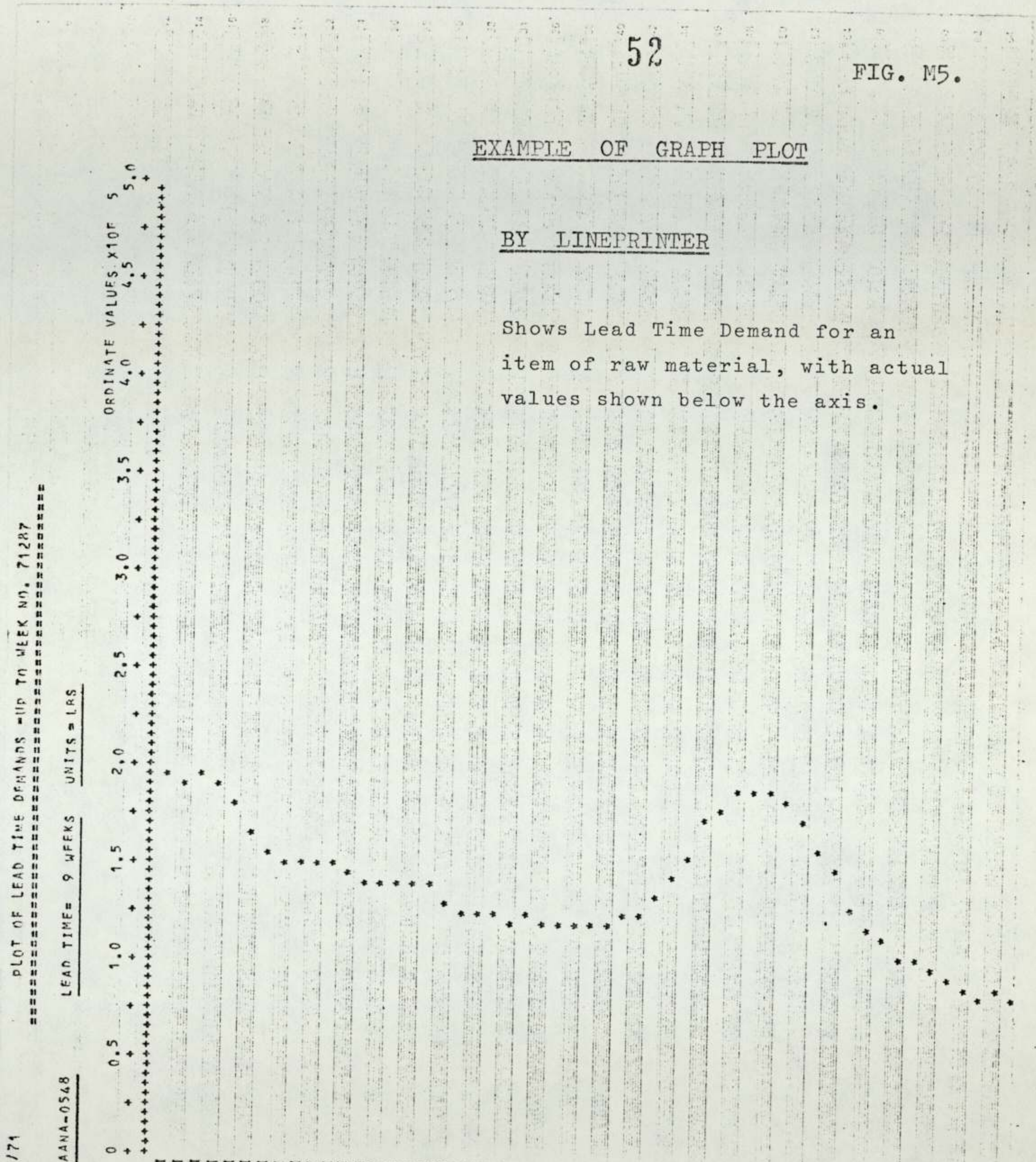
Thus the plotting routine was included as an optional

FIG. M5.

EXAMPLE OF GRAPH PLOT

BY LINEPRINTER

Shows Lead Time Demand for an item of raw material, with actual values shown below the axis.



printout from the forecast program.

1.11.4 Reaction to the Graphs

The computer produced graphs generated considerable interest amongst members of the Systems/Programming staff, none of whom had previously thought of presenting their computer systems output in such a form.

Several managers were surprised to see the pattern of sales or demand, data which they handled frequently but had not considered in this way before.

The Director of Marketing, on seeing one such sales pattern checked through a series of monthly figures from his files and discovered that they did show the same pattern as indicated by the graph. He commented that if he had known before that the trend had started it would have been useful information. In fact he already had the data but the author noticed that each successive month's figures were separated by a number of sheets of other information and the Director obviously not often compared one with the next.

These and similar observations lead the author to feel that by seeking out such existing management information and presenting it in a more suitable form, new and useful management information can be generated. Such information has evidently, in some cases, great potential value to the firm and illustrates that the way in which some information is presently displayed (or obscured) results in its potential value being under-utilised.

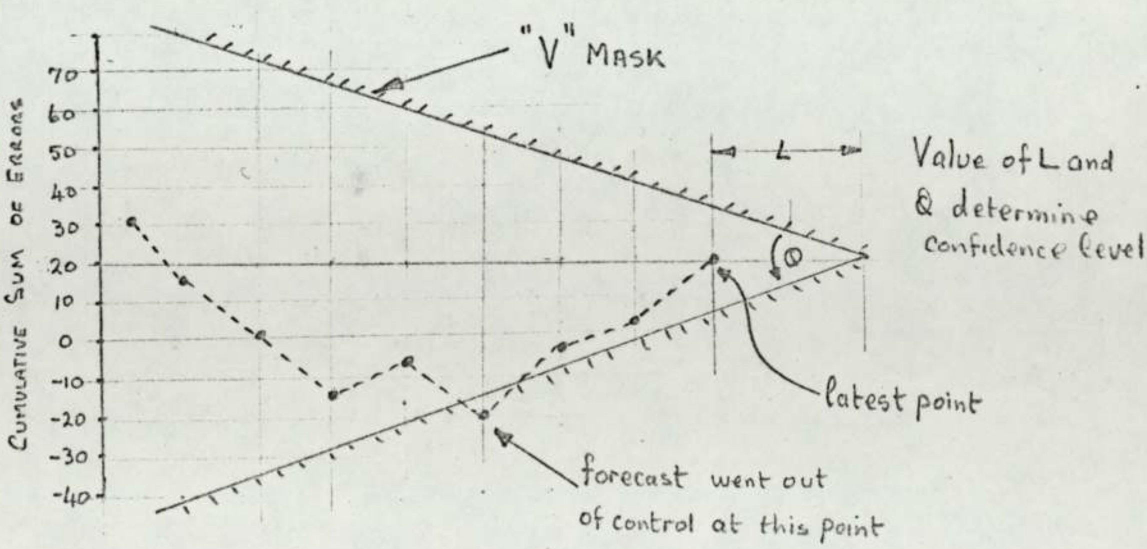
.11.5 THE GRAPHICAL 'CUSUM' TECHNIQUE FOR MONITORING FORECASTS.

A useful graphical method for monitoring forecast accuracies is the cumulative sum (Cusum) method which is now being used widely in industry. It has the advantage over most other methods in that as well as indicating that there has been a significant change in demand level it pinpoints the time at which it occurred.

The sum of the last 1, 2, 3,.................n periods' forecast errors are plotted on a Cusum chart and show clearly any repeated tendency to under or over forecast. By constructing "V" mask limits , an acceptable accuracy can be imposed on the Cusum figures, indicating if significant errors have occurred <u>and</u> when the change that caused these errors first took place. Knowing the time of occurrence, the demand level prior to the change can be ignored in future forecasts as unrepresentative of current demand.

The greater the included angle of the "V" mask the wider the confidence limits, the limits normally being defined as a linear function $\pm$ ax(i + b) for periods i = 1 ....n in the past. Harrison & Davies (1964) show the derivation of a and b to give the required confidence limits.

Below is an example of a Cusum chart with V mask placed on the point plotted as the last period's forecast error.



1.12.0 THE REGULAR FORECASTING PROGRAM

This was a straightforward program to be run weekly and produce forecasts for each stock item. Part of the suite of COBOL programs accepted the last week's demand figure for each item and updated the DEMAND-HISTORY file shifting all the remaining figures back by one week (thus loosing the oldest record but always maintaining 150 weeks history).

The FORTRAN program would read in this updated tape (which also contained details of forecast method, parameters and last forecast statistics for each item). Forecasts would be produced and printed out, and the DEMAND-HISTORY file updated with new forecast statistics.

When the re-written COBOL programs were ready, testing began of the regular tape updating/forecast system. Considerable difficulties were then encountered in the compatibility of tape files passing between the two programs, although separately they appeared to work satisfactorily, and file layouts were compatible with those specified in the ICL manuals. This problem was aggravated by another increase in job 'turnround' time. To help overcome this the author learnt how to operate the computer and could then run tests during the night when the machine was not normally in use.

Despite this, the problem was not fully overcome. Again, the Materials Controller was expressing severe misgivings about the extra amount of clerical work the system would generate and he did not produce the necessary historical data required to establish forecast methods for each item and initialise the system files.

At about this time the Management Services Manager was being urged to initiate work on forecasting the sales of finished goods. Since sales forecasting seemed a more important company problem, and in view of the reduced involvement of the Materials Controller, the author was instructed by the Management Services Manager not to spend more time developing the materials forecast system but to proceed immediately with an investigation into Sales Forecasting.

1.13.0. SUBSEQUENT DEVELOPMENTS IN MATERIALS CONTROL.

As indicated previously the author was directed to turn his attention to Sales Forecasting before the computerised materials forecasting system had been fully developed.

1.13.1. Stock Reductions.

Despite this the Material Controller was able to use the output from the forecast/simulation programmes to significantly reduce his target stock level for the biggest value stock item (which had been used in testing the programmes). This was Monel Alloy - cost c. £1,500 per ton. Over a number of years the stock target had been slowly reduced to 100 tons by successive lowering, in small steps, and monitoring the effect. Simulation enabled this process to be safely accelerated by testing various lower stock levels without any direct consequence of stockout. A 50 ton target gave 78% protection whereas a 60 ton target gave 92% protection. This was considered reasonable and was adapted as the new stock target - a potential saving of £60,000 saving in capital invested. There was in fact some danger in doing this since re-ordering was not being supported by the same forecasts used in the programmes. (The manual forecasting system remaining as described in section 1.4.3).

1.13.2. Problem of delays in computer processing.

Whilst proceeding with the sales forecasting project the author was urgently requested by the firm to specify the basic requirements of a computerised materials stock recording system. This was done with due regard for the urgency expressed by the Data Processing Manager (the author's industrial supervisor) who did not eventually read the report and took no action to produce such a system. Preparing the report did however have one benefit. The investigation made clear one important additional reason why the idea of a batch-processed computer forecasting system was mistrusted by the Materials Controller, although he never stated it as such. This was not just the extra clerical effort involved but also the time delays inherent in having the information generated.

The existing forecasting system for major material items was, each Friday, to obtain the last of the previous day's stores withdrawal figures; compute the last week's total demand; produce a forecast and then on the same day place replenishment orders for delivery one lead time hence. Under a batch processing system (i.e. with no instant link to the computer) the previous day - and/ or week's - figures would have to be written onto punching documents; sent for punching onto computer cards; run on the computer and the results returned to his office. Also at some stage the data punched would have to be validated by the Materials Controller and any corrections returned for re-punching and re-running before he could have a full set of results. The present computer operating system probably could not guarantee to provide complete results until the following Tuesday or Wednesday,- well after the Controller needed it.

Having realised this the author pointed out the problem to the Production Manager who, it would appear (like the author) had not been aware of it before. The Materials Controller's case for a more sophisticated calculating machine to carry out the work in his own office was strengthened. Soon afterward the purchase of a better calculator (to replace the small comptometer type previously in use) was agreed to. Although this represented an increase in the complexity of calculations that could easily be carried out it did not completely satisfy the Controller's request for a 'desk top computer'.

1.13.3 Revised Manual System

Several months later the author again discussed the overall situation with the Materials Controller, who decided to revise his existing system to carry out more sophisticated forecasts manually and also generate more information on stock values etc. He has not yet fully planned these revisions although in preparation some ad hoc additions have been made to the KARDEX recorded information. The manual system would require that the last week's forecast, the last week's demand and current forecasting statistics be read from the KARDEX; a forecast would be made (according to results found from the optimum forecast method program) and the new forecast entered onto the KARDEX Record. The more versatile the calculating machine available, the more easily and quickly could the forecasts be made, and the more sophisticated the methods which could be reasonably used. Input to the optimum forecast method and simulation programs will be by punched cards, and the programs will probably be re-run every 9-12 months to check that the methods/factors for each item are still optimum in the light of the current demand pattern.

A disadvantage of the manual system is that the clerical workload will probably prohibit the computation of additional statistics to monitor and report the accuracy of past forecasts. Such a system is probably as good as can be produced with the present equipment since it keeps the information readily accessible to the Materials Controller and should, with some extra clerical assistance, be completed quickly enough for him to place his orders on Fridays.

The author has improved the options provided by the forecasting/simulation programs in a number of ways, including the facility to enter data in 'free' format and for units of demand to be either in lbs, kgs.or mixed. This latter point saves the user from converting old historical data to kgs. All printed figures are shown as kgs.. A short manual has been written to enable the user to set up his own computer runs whenever he wishes to.

1.13.4. General Observations and Suggestions for Future Action

Observations

Stewart (1971) indicates that it may often aid successful systems design if the analyst works within the 'user' department rather than isolated in a 'systems' department, and it is felt, retrospectively, that this would have benefitted the author in the Materials Control investigation. Had this been so it is thought that problems such as the Controller's time constraints would have been more quickly identified and that as the author would have become accepted more as a member of their team rather than just a frequent visitor from another area that the systems work would have proceeded more smoothly.

In retrospect the existence of a partly designed and programmed system (1.5.0) at the outset of the author's investigation probably hindered rather than helped the progress of the project.

Recommendations

It is recommended that the Materials Controller should receive continued support in establishing a more scientific method of forecasting and stock target fixing. He should be assisted in preparing a case to show wether or not the use of a more sophisticated calculator or computer terminal is justifiable. The possibility of employing simple histograms for forecasting (such as a simplified version of that shown in Appendix B) should also be considered.

CHAPTER 2

SALES FORECASTING

CHAPTER 2

SALES FORECASTING

INDEX

2.1.0 SUMMARY

Following work on a raw materials forecasting system the author was required by theCompany to carry out an investigation into the feasability of producing usably accurate sales forecasts from a computerised system.

This chapter records the stages of the work carried out: defining the objectives; obtaining, checking and analysing data; experimenting to find suitable forecast methods; and the setting up of a regular data capture and forecast system.

Accuracy checks, made when the regular system was initialy run revealed a number of errors and omissions in the data being collected by the Company's Order Processing System. Since the Company is not prepared to improve the O.P. system it has been necessary to discontinue the forecasting of the system, at least until such time as their proposed new Order Processing System is in operation. To ensure that this new O.P. System correctly processes and records orders in a form suitable for generating forecasts and other management information. The author has made a number of recommendations to the Company. The report containing these appears in Appendix A.

During the sales forecasting investigations - as also during the materials forecasting work - a number of observations were made about the acceptance of computer printout and other related documents. These are reported as they occurred and expanded on further in Chapter 3.

SALES FORECASTING

2.2.0 BACKGROUND TO THE PROJECT

2.2.1 Company's Multiple Objectives

Pressure from three areas within the Company had been put on the Management Services Department to produce a system to forecast future sales. This pressure arose firstly at Board level - a request for medium term revenue forecasts; secondly from the Production Office - requesting automatic forecasts for each product (to supersede their own manual forecast system); and thirdly from the Materials Controller, who pointed out that accurate sales forecasts would be an important guide to future raw material demand.

The Firm's requirements defined two broad sales forecast objectives, the feasability of which were to be investigated:-

(1) Short term forecasts for scheduling production and estimating short term cash flow, and

(2) Longer term forecasts for aiding corporate decision making.

2.2.2 Existing Forecasting Procedures

The requirements were not for entirely new forecasts, but for forecasts to improve and complement those already being generated.

In the corporate area several types of forecast were and still are in use. The shortest term forecast is made once during each accounting period (A.P.) for the revenue expected during the following A.P. This forecast is compiled by the Marketing Director from estimates by the various product Sales Managers. It was discovered that in at least one sales area the manager delegated his part of the forecast to one of his subordinates who in turn admitted that he did not have much information to work on and did not spend much time making the forecasts !.

A second forecast, this time produced by a subjective concensus of senior management's information was for the current year's expected revenue, and was reforecast every three months (thus reducing the forecast horizon each time). This forecast was required for inclusion in the quarterly report sent to the parent corporation in Boston, U.S.A.

The other corporate forecast was much longer term, covering the next three to eight years, produced again by senior management for corporate planning purposes.

An entirely separate set of forecasts are produced, monthly, by the production offices enabling them to plan production over the subsequent three months. The main forecasts are made in the rivet production area and are based on outstanding orders for the next three months, plus any overdue orders, plus an allowance for the rate of incoming orders. This total is divided by 13 to give the average weekly production required (for each product). Production is not formally scheduled following this forecast to account for the pattern of demand within that three months except for production control's subjective adjustments to suit the ongoing situation of materials and labour availability or to satisfy particular orders being progressed.

2.3.0 DEFINING THE PROJECT OBJECTIVES

Given the existing state of forecasts and the need for their improvement there seemed to be a number of distinctly different requirements, each of which would require different approaches to their solution.

In order to limit the scope of the project to manageable proportions, and to concentrate attention on solutions potentially most beneficial to the Company, it was necessary to define more closely the project objectives.

2.3.1 The Parameter to be forecast

The project had been loosely dubbed 'Sales' forecasting, but this did not define for what quantity forecasts were required. 'Sales' mean different things to different members of an organisation. A salesman may count a 'sale' as being made when the customer gives him the order. To an Accountant the 'sale' may not be made until an Invoice has been sent, or even until payment has finally been received. The Production Controller or Warehouseman may interpret a 'sale' as the point at which the goods are dispatched from the factory.

These different interpretations of a 'sale' have obvious differences in the time at which the sale is said to occur and possibly in the quantity or value of the sale (since order details may be changed or cancelled between the first order placement and its eventual dispatch).

The value of the forecasts to the Company were examined to determine what parameters to try to forecast.

Forecasts are estimates of future occurrences and as such are useful for planning future Company policy and production. If this planning has been inadequate the Company may not be able to supply all its customers with the quantities of products they require, at the time they require them. As mentioned in chapter 1 the Company has become increasingly aware that in order to maintain its share of the market it must improve its 'service' to customers by providing delivery of the required quantity of goods on the requested date.

Thus it was decided that FORECASTS OF CUSTOMER DEMAND would be the most useful to the Company, since it would enable them to plan more effectively to meet that demand, both in quantity and required delivery date.

2.3.2 Forecasting Horizon

The Company's objectives have indicated requirements for short, medium and long term forecasts. It did not seem likely that the same method would produce adequate forecasts for all three categories, since longer term future demand would be more dependent on changing external market influence than would the short term demand.

Short term forecasts would aid production planning at the operating level whereas medium and longer term forecasts would be useful for planning future labour and machinery requirements. Both possibilities would be valuable to the Company but it was decided that the former (short term) would be the more important - ensuring that in the future there were still (satisfied) customers to place and create repeat orders , by punctually meeting their present demand.

All production cycles at the Company take less than three months, so it was decided that it was reasonable to use a THREE MONTH FORECAST HORIZON, complementary to the present manual system which makes and uses forecasts for this period.

2.3.3 Frequency of Forecasting

A production plan must extend some useful time into the future. Too short a planning period would not allow time for machine changeovers and setups. Too long a period would not allow the flexibility to follow changes in demand. There is a need to review and revise plans while they are still current and not at the end of their horizon, since each review period would otherwise end with an unusably short forward plan. It could be seen that if the three-month forecasts and production plans were reviewed once per month this would allow production to be geared according to current demand data whilst always providing a usefully long forward plan.

There were three possible choices for this 'monthly' review period. Forecasts could be made at the end of each accounting period (A.P. - the time at which the Accountants close their books for analysis). A.P. s at the Company occur in an irregular series of four and five week periods. Forecasts by A.P. could be useful for the revenue forecasts already discussed but would not be directly comparable one with another unless corrected for the period differences. Direct comparison is necessary both in a formal mathematical forecast and for general management information about trends and demand patterns. It was felt that forecasting for irregular periods would lead to great practical difficulties in determining optimum forecast methods and in producing a regular forecast system. It would not be particularly useful for production control since production was not geared directly to Accounting periods.

The second possible review period was the calendar month. Being another irregular length period it had similar disadvantages to the A.P., and had no particular relevance either to Company accounts or to production.

The third possibility was for a constant four or five week review period. A four week period provides a 12 week 'quarter' compared with production control's existing 13 week horizon and would be readily usable for their purposes. Being a constant period analysis comparison of results would be more straight-forward than an irregular period. Revenue forecasts by A.P. could be produced by combining appropriate proportions of the overlapping four week periods. (e.g. if the start of a five week A.P. coincided with the start of the second week of a four week forecast period then the A.P. forecast would consist of 3/4 of that four week forecast plus 2/4 of the following four week forecast).

Since it had already been decided that forecasts for production planning were an objective, and considering that constant period forecasts were the most practical, it was decided to FORECAST ONCE EVERY FOUR WEEKS.

2.3.4 Which Products/Groups to Forecast ?

The Company produces a wide range of products and it was felt impractical to attempt to forecast all of them, at least at the start of the project.

One group of products - rivets - yield a considerable proportion of the Company's revenue. Production is controlled by members of a rivet production office who are not concerned with other products, and this office had already expressed interest in sales forecasts. Rivet market competition was likely to grow faster than for other products and it would be thus most important to improve and maintain good customer service for that product.

For these reasons it was decided to concentrate first on FORECASTS FOR RIVETS.

Two levels of forecasts could be made: BY INDIVIDUAL PRODUCT - useful in production control, and BY GROUPS OF SIMILAR PRODUCTS. The product groups chosen were

similar to groups already chosen for other management information systems at the Company, being by metal type (Steel, Monel Alloy, Aluminium Alloy and Copper) for the range of 'open' rivets plus a single group for all 'sealed' rivets (which are produced by a different process than the open rivets). These product group forecasts would be useful as general information to the Production Controller on the proportion of machines required for each group and also as an indication of the raw materials required. Furthermore by multiplying the group quantity forecast by the average price for each group the management's requirement for short term revenue forecasts could also be satisfied.

2.3.5. Pareto Analysis.

A COBOL computer program already existed at the company to carry out Pareto Analysis* of past order quantities. Results from this program were used to highlight the relativ importance of the product groups, and to periodically re-examine the pattern. The program had been written originally for one specific application and thus required re-programming every time a manager requested other information of this type.

It became clear that a more flexible form of the program could provide management with a way of obtaining up-to-date estimates of sales proportions more quickly than through the old manual system.

The author specified a number of changes required to make the analysis program more flexible and easy to set up, but it took several weeks to convince the Management Services and Data Processing managers to have the program improved.

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*Pareto Analysis - named after the mathematician who suggested it - consists of sorting a series of values into descending order of magnitude and expressing each of them as a percentage of the total of all values in the list. A cumulative percentage may also be computed.

These program changes have now been made and the author has been able to circulate management with a memorandum pointing out this rapid 'information facility' which can now be offered by the Management Services Department. The main options offered are as follows.

(i) — Analysis within the following product groups:

All. Pop Open Rivets
Alloy " " "
Monel " " "
Steel " " "
All Sealed Rivets
All Rivets (Open and Sealed)
All Eyelets
All Tools
All Items on a file - (This last facility enables any unusual/uncatered for groups to be compiled on a file by use of the standard ICL 'FIND' and MERGE FIND facilities and a Pareto Analysis of this group to be carried out).

(ii) — Analysis within the following 'depth' of part number:

first 3 characters - indicates Rivet Metal & Head types
" 6 " also body size
" 8 " also mandrel type
" 10 " also mandrel length
all 17 characters - also finish and clip assemblies.

(iii) — Pareto analysis in descending order of QUANTITY ordered -
Pareto analysis in descending order of REVENUE earned.

(iv) Analyses can cover any period up to four years (the oldest data available) - most conveniently in 3-month increments.

The program is being used increasingly by a number of departments including Rivet and Eyelet Sales, Research and Development, Toolroom and also periodically by senior management.

A general observation whilst carrying out this exercise has been that within the Management Services Department there seems to be only a limited interest in, and appreciation of, the value to the Company of the management information it does (and potentially could) generate. It is felt that this situation is probably detrimental to the department in its task of producing valuable management information (and information systems), although it may have been partly caused by senior management not (in the past) seeming ready to make sensible use of the information.

2.3.6 Summary of Objectives

The defined OBJECTIVES OF THE EXERCISE were thus as follows:-

To investigate the feasability of forecasting the DEMAND for RIVETS by PRODUCT and by PRODUCT GROUP. These forecasts to be made once EVERY FOUR WEEKS and to cover the subsequent THREE, FOUR-WEEK-long periods.

2.4.0 THE BASIC DATA

2.4.1 Computer Records

Approximately two years before the sales forecasting investigation began, the Management Services Group at the Company had been made aware of the need to collect sales data preparatory to such an investigation. They already had in operation a computer system processing incoming orders, recording outstanding orders and producing acknowledgements and invoices. To this they added a routine which simply recorded, on magnetic tape, details of all orders processed. This was known as the 'YEARSORDERS' file (Y.O.) and included the following details:

Approximate date of receipt of order,

Quantity of product required ,

Date customer requests delivery to be made ,

and for orders requesting a number of scheduled deliveries

Date of first delivery ,

Number of deliveries ,

Period between deliveries ,

Where a schedule was not spread over exactly equal periods an approximation was made but this would not give rise to significant errors in the monthly analyses since the approximations were for less than one week. A separate file was accumulated for each quarter, and the department had writen several programs to produce order analyses from this data.

Thus the Y.O. file was the obvious choice of basic data for the feasability study. The alternative data sources were either the order records (from which the computer information was derived) or the rivet Production

Office's records. The first alternative would have been a duplication of the computer records, and in any case with up to 2000 rivet orders being received each week this would have presented a very large data extraction task. The second alternative was the 'build-up book' into which Production Office staff entered orders against the appropriate product, for the appropriate month. Where it was known that a customer's requested delivery date could not be met the order would be placed in a later month's total and the customer informed of the 'promised' delivery date. The customer might decide to buy elsewhere if his requested delivery date could not be met and cancel his order with Tuckers. Thus the build-up-book would not always reflect true customer demand when there had been stock or production constraints on delivery.

2.4.2 Checking the Data Accuracy

The total orders received for delivery in each four-week 'month' for the duration of the file history were to be extracted from the Y.O. file. This data would then be used to test, by retrospective simulation, the accuracy of various forecasting methods. For this purpose it was clearly important that the data should be a reasonably accurate representation of the real demand that had occurred.

The first few months data had to be ignored since there would have been a significant number of orders placed prior to the date of initial tape creation, with delivery requested for these early months. In the event only the last 15 periods' data out of an available 23 periods were used at this stage. This shortage of data meant that it was not possible to split the data and thus use the first part for establishing forecast methods/ parameters and the second part to test their continued validity.

Figures from a manual recording system were available indicating the quantities dispatched from the factory. Dispatches during a given month would not usually equal 'demand' (i.e. customer required quantities and delivery date) the former tending to lag the latter. However, it was estimated that the errors generated by different amounts of lagged orders at the beginning and end of a period would become acceptably small if the period used was relatively long - thus the total quantity of computer recorded orders for delivery in a one year period could reasonably be compared with actual dispatches during that year.

This check was carried out for each of the separate product groups, each split into home and export markets. Month by month demand figures for 1971 were obtained from a special run of an existing Order-Processing program.

Comparing the two figures showed that the computer recorded demand figures were all between 8% and 15% different than dispatched totals. Upon investigating these discrepancies a number of cases were discovered where for all, or part, of the period examined certain classes of orders had not been computer processed and hence not included on the Y.O. file. As elaborated in 2.4.3 difficulties were encountered in this investigation but the omissions identified and corrections applied were as follows:-

(i) For the first half of the 1971 data details of orders dispatched <u>to</u> the Company's London warehouse were recorded as orders on the Y.O. file. There was thus a period of nearly two months when no London Office orders were computer processed, through subsequently details of orders for dispatch <u>from</u> the London warehouse were recorded (thus only giving an approximate indication of dispatches from the factory).
To correct for the omission the Y.O. figures were increased by the appropriate proportion of average London Office orders.

(ii) Rivets are dispatched either in standard cartons ('Bulk' dispatch) or smaller packing units ('Small-Pack' dispatches). Dispatches from the Small Pack area are to two types of customer: 'Factors' and individual smaller customers. The latter class was not recorded on the Y.O. file until the last four month of the year in question and have been thereafter).
The omitted figures were estimated from the Small Pack department's data and the Y.O. data corrected accordingly.

(iii) For the first six months of 1971 <u>Deletions</u> had not been computer processed. These occurred when major changes of delivery quantity or schedule were to be recorded or when corrections to computer file records were necessary. It was discovered that when deletions <u>were</u> processed they often contained only the quantity to be deleted and not the date on which they had been required. Thus in analysing the Y.O. file it was only possible to make a 'blanket' reduction for deletions over the whole year, including a correction for the period when they had not been processed. The author recommended to the Data Processing Manager and Management Services Manager that in future deletions should include the date on which delivery had been requested.

- When the corrected Y.O. figures were again compared with dispatches they were found to correspond within 2 - 3%. Since the data omissions had (with the exception of deletion dates) been rectified the Author felt that the Y.O. data now should be a sufficiently accurate basis for the forecasting investigation.

2.4.3 Difficulties in checking data

Considerable difficulty was encountered in trying to establish possible causes of the data discrepancies.

The first of these difficulties was the almost total lack of documentation of the Order-Processing System. The clerical system was functioning mainly according to routines passed on verbally, and the Data Processing staff were not fully aware of what each of the programs could or did do. Thus to establish where data errors or omissions might be occurring it was necessary to enquire from people who were concerned with running the system.

Here arose the second difficulty - How, without the prompting of a background knowledge from systems documentation, to elicit useful answers to questions such as "Do you know of any class of orders which do not go through the computer system?". The author observed that the questionee would often - after some considerable thought - say "No" to this question. However, if later they were asked about a specific class which the author now suspected, they would often then remember, and confirm that those particular orders were not after all put through the system.

This led the author to conclude that in any such situation where abstract questions are asked during an investigation that more complete answers are likely if some kind of prompting can be made. This would be the case in a systems investigation where a user is being asked to specify all the information he thinks he needs from the system, and suggestions for one form of prompting list which would be useful are explained further in sections 3.2.3 and 3.2.4 of this dissertation.

2.5.0 PROCESSING THE DATA

The YEARSORDERS file contained much information which was not of use for forecasting and it was suggested to the D.P. Manager that it would speed up processing if a shortened version were to be produced, containing only the relevant data. He agreed that this would be the case and instructed a COBOL programmer to write a program to do this, following the author's specification. This shortened file was named 'CONDENSED' file.

During the investigations of forecast method two main requirements arose for analysis of the Y.O. data.

The first was to extract the total quantity of orders (for each product group) requested for delivery in each four-week period, and a FORTRAN program was written to accomplish this. Although FORTRAN is very suited to the required mathematical analysis the language has a limited capacity for handling alphabetic characters. During analysis whenever it was necessary to establish the product group of a given part number its alphabetic content had to be examined. This entailed calling up special software routines each time. To minimise such character handling the CONDENSED file was first sorted into part number order using the standard ICL software program #XSMC. (The sort time was greatly shortened by using the shorter CONDENSED version instead of Y.O. there being less characters to be transferred to and from the files). Thus for each part number the product group had only to be determined for the first record read, it only being necessary to check for a change of part number on subsequent order records. At a change of part number the order history was added into the appropriate group total and also recorded on a magnetic tape file 'ORDHIST'.

<u>for example</u> - the logic associated with the following sequence of sorted part numbers would be:

APD424	-	Record the part number and analyse data for that part number
APD424	-	Check,- part number is same as recorded - analyse data for that part number
APD424		" " " " " "
APD429	-	Check - change of part number - record totals for last part number - record the new part number - zerorise accumulators - analyse data for new part number.

When the entire CONDENSED tape had been read in, the group totals were also written to the tape and a hardcopy record printed.

Later in the investigations came a need to establish how far in advance orders had been placed. Thus the author wrote a similar analysis program but for each part number the following had to be established: The period in which the order was placed, the period in which delivery was required and thus the number of periods in advance that the order had been placed. (The use of subscripted arrays was found invaluable for this programming application). Again a magnetic tape file was produced recording both part number and group details. A further COBOL program (written by a member of the D.P. staff) produced a hardcopy print of the required groups.

Other analysis which became necessary (e.g. identifying all deletions on the file or all orders placed after a certain date) were carried out by using the ICL package 'FIND' which can be used to extract particular data from one file and then produce an edited file or a printed record.

One problem encountered with the FORTRAN programs was that to analyse the large volumes of data, required very long continuous computer runs (about 7 hours in some cases). This was mainly due to the low power of the Company's computer in handling floating point numbers. The author often found it was necessary to operate these programs himself - at night-in order to get them run without too much delay, the Company not being willing to pay an operator or have the work done on a more powerful machine outside the Company.

2.6.0 ESTABLISHING FORECASTING METHODS

2.6.1 Use of a Computer Package

The use of ICL's package SCAN had been rejected for use in materials control (1.8.0) but its usefulness was again reviewed for sales forecasting.

Separate forecasts for one, two and three periods ahead were required but as pointed out in Chapter 1 SCAN only optimised forecasts for one period ahead. It was envisaged that forward order loading would give a useful indication of future sales but SCAN had no facility for forecasting such partially known demand and it was decided not to use SCAN for sales forecasting.

2.6.2 Forecasts Based on Past Demand

The optimum forecast method program developed for use in materials control (1.9.0) made forecasts based on past demand. It was straight-forward to use the same program for demand forecasts by feeding in four-weekly demand values instead of weekly stores with-drawals. Appendix C contains details of this program.

Of the forecast methods included in the program the simple exponentially smoothed average (as detailed in 1.9.2) generally gave the best results, the rapidly changing demand levels being too sudden and short lived to enable Trigg's adaptive forecast method (1.9.2) to respond.

Lagged adaptive Smoothing as suggested by Shone (1.9.2) gave approximately the same accuracy as exponential smoothing.

For most product groups the month by month demands presented a very varied pattern and the 'historical' forecasts passed roughly through the mean of the values, not being able to anticipate the short period peaks and throughs in demand. The line marked 1 in figure S1 illustrates this.

Clearly these forecasts were not likely to be better (and would probably be worse) than the subjective forecasts which managers could make if there were in possession of the same data.

It seemed that more information would be required to produce better forecasts - and this was readily available in the form of forward order loading.

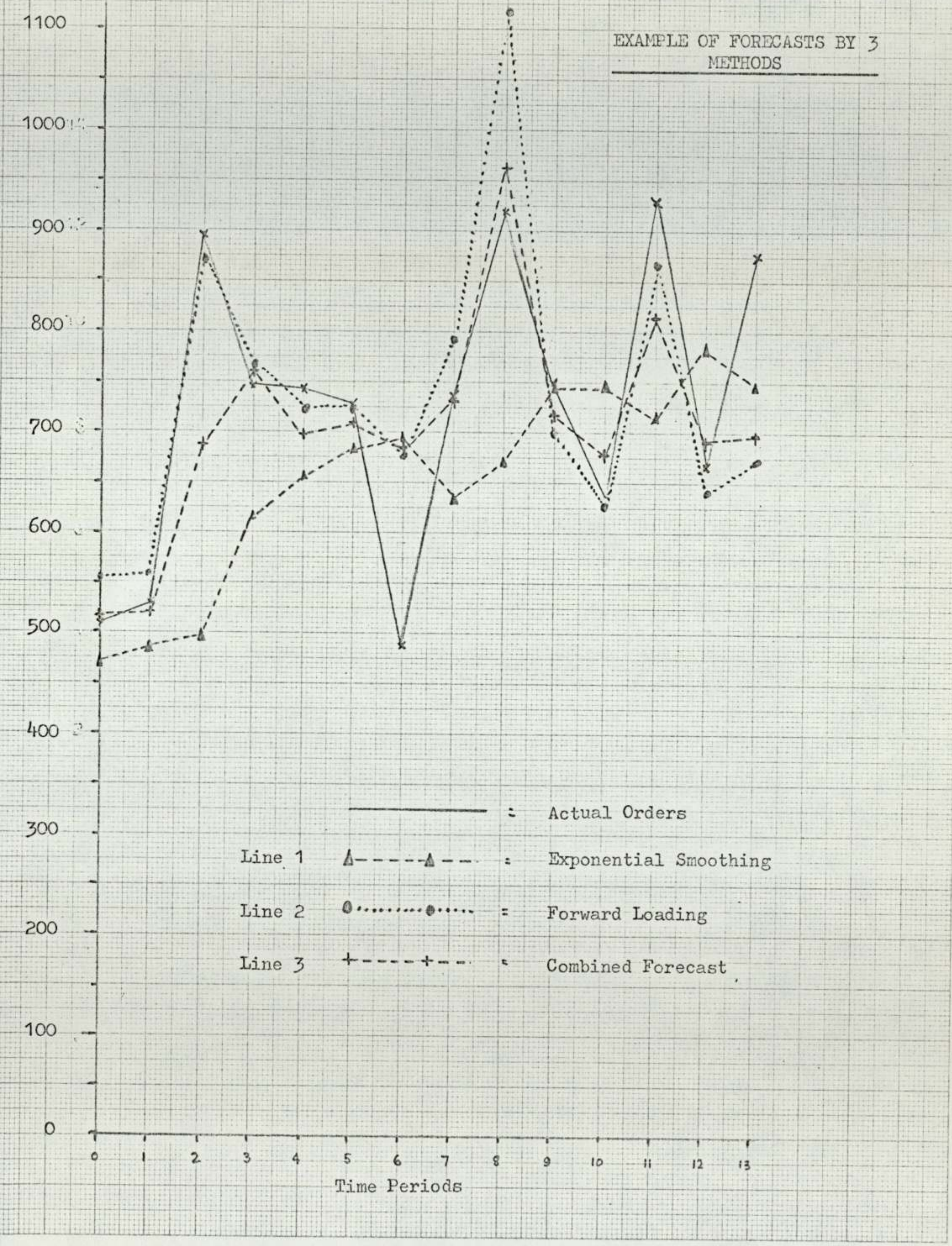
2.6.3. Forecasts Using Forward Order Load.

As explained in 2.5.0 the quantity of orders received, and the proporation of these ordered one, two, three....... months ahead of required delivery had been obtained from a purpose written program.

From this data it was clear that in almost all instances forward orders beyond three periods ahead were relatively small (mostly less than 15%) and that they were unlikely to give a good indication of final order load. However, for data of orders up to 3 months ahead, pilot forecasts (multiplying forward orders by an appropriate fixed proportion) showed potential improvements in forecast accuracy. This method was thus incorporated into the existing forecasting optimising program.

FIGURE S1

EXAMPLE OF FORECASTS BY 3 METHODS



(1.9.0) Advantages of this method compared with using regression analysis to arrive at the proportions were that the results would automatically be plotted out on the same graph as the historical methods already tried (2.6.2) - for direct visual comparison - and that alterations could easily be made to the forecast method to test other possibilities.

Thus the forecasts became

$$f_t+1 = \frac{\text{forward order load}}{cp}$$

where f_t+1 = forecast for a subsequent period

cp = constant of proportionality (in range 0-1.0)

(e.g. if 85% of orders were placed in advance then this constant would be 0.85)

The programme was suitably modified to accept both actual and forward loading data from punched cards and to accept from a control card the range of proportions to be tested in the simulation.

This method did usefully predict peaks and troughs in export demand. In 63% of cases for 1 and 2 months ahead, it gave a significant* reduction in sum of squared errors (c.f. 'historical' forecasts). Forecasts of home demand were improved by this method in 50% of cases but did not yield significant improvement in S.S.E. Three month ahead forecasts were not improved by the forward load method, 38% of cases yielding significantly higher S.S.E.'s.

From the graphs it could be seen that the correlation between forward orders and actual orders was not a stationary proportion, especially for two and three month ahead forecasts, since the forecasts - though reflecting the sense of the peaks and troughs - were over-estimating their magnitude.

Reducing the multiplying factor would improve the accuracy of high forecasts but reduce accuracy of the

*Differences in S.S.E. being significant at the 5% level using the F test .

See appendix D for tables of results.

low forecasts. It was concluded that an overall improvement could be made by, in some way, smoothing the forecasts relative to their deviation about the mean demand.

2.6.4 Automatically Varying forward Factor Proportion

An extention to the previous method was to vary the constant of proportionality in the equation by exponentially smoothing the value of the multiplying factor according to the actual proportion last time.

i.e. where d_t = last period demand

o_t = prior orders for that period

the actual proportion, $A = \frac{o_t}{d_t}$

and the smoothed proportion for use in the next forecasts was $= Cp_t = \alpha A + (1-\alpha) \times Cp_{t-1}$

where Cp_{t-1} = last calculated Cp

and α = smoothing constant

The results were not as good as for the fixed constant (8-14% increase in S.S.E.). Thus the constant factor method was retained - it being only necessary to re-simulate periodically to check the optimality of the proportion used.

2.6.5 Combined Forecasts

The best measure of mean demand seemed to be the smoothed average forecasts produced from historical data so it was decided to try combining this with the forward load forecasts.

Bates and Granger (1969) point out that two (or more) forecasts may differ by one being based on variables or information not considered in the other, or that the forecasts make different assumptions about the relationship between the variables, and that combining such forecasts can (but does not necessarily) lead to better forecasts. They considered five different methods of combination, four concerning past forward error magnitudes and one concerning the covariance of errors.

It was unlikely that a fixed combination of the two forecasts would be optimum for all groups forecast and for all time, so some form of adaptive combination was required as they suggested.

The method chosen was based on a suggestion from C.D. Lewis (Diploma in O.R. Course Notes, Aston University) and is an extention of one of Bates and Granger's methods. This involved monitoring the past accuracy of each forecast method separately in terms of the Mean Absolute Deviation (derived in 1.9.2), weighting each forecast according this relative accuracy and summing to get a final forecast. For example if the forward load forecast (F2) had recently been more accurate than the historical forecast (F1) then the final forecast might be made up of (say) 0.7 x F2 + 0.3 x F1.

The forecasts are combined according to the inverse proportion of their MAD's, thus :

where $F1_t+1$ = forecast by historical method

$M1$ = latest MAD of historical method

$F2_t+1$ = forecast by forward load method

$M2$ = latest MAD of forward load method

Then combined forecast, $F3_t+1 = \left(\frac{M2}{M1+M2}\right) \times F1_t+1 \left(\frac{M1}{M1+M2}\right) \times F2_{t+1}$

(This forecast method could easily be extended to combine more than two other methods).

The combined method was included in the forecast optimising program in such a way that it first found the optimum factors for use in methods 1 and 2 and then produced the third forecast as a combination of these optima.

From the table in appendix D it can be seen that for 1 and 2 month ahead export forecasts this yielded significantly lower S.S.E.'s than one or both other methods separately. For 3 month export forecasts however the combined method was better in only 25% of the cases. Home forecasts were only significantly improved in one case, which was to be expected since the forward load forecasts had not been as accurate as for export forecasts. Line 3 on fig. S1 shows an example of the combined forecast. In some cases of the one and two months ahead data the forward load forecast still gave a significantly better result - showing that the orders/actual correlation was very high in these cases. Other cases, especially home forecasts three months ahead, were still most accurately forecast by the historical method.

At this stage the forecasts were becoming usefully accurate and it was decided to establish whether the potential forecast users shared this view.

2.6.6. Indicating Forecast Accuracy Range.

It was realised that a 'point' forecast of a single specific value was very unlikely to exactly equal the eventual demand but was an indication of the most likely value of demand expected by the forecast method in use.

To make the forecast information more complete the point forecast should be accompanied by an indication of the range about that forecast value in which the actual value was expected to lie, and the associated probability of it doing so. This might aid the users' acceptance of the results since they would be forewarned of the likely precision and thus be less likely to discredit the forecasts' future usefulness just because it did not come very close to the actual value. If the user can decide to use only those group forecasts which look usefully precise then the forecasts are likely to maintain their credibility. If, instead, he attempts to use them all, the credibility of <u>all</u> the forecasts may be lost as the result of <u>one or two</u> difficult-to-forecast groups or items failing to be precisely forecast.

The forecast error range can be usefully used in planning production and inventory levels. If sufficient stock is available to cover any likely error the production need only be geared to producing the central forecast value. If however stocks are low then production must be geared to producing to the upper limit of the forecast in order to provide similar protection against delivery backlogs.

There are various ways of deriving the forecast range (and the associated probability of the actual demand falling within it). One method is to examine the range of errors which occurred during the simulation runs. For example, if the simulation covered 20 periods, taking the 18th highest error gives a range about the forecast value in which the actual value can, for 90% of forecasts, be expected to lie. The range determined by this method must be reviewed periodically to take into account more recent trends in accuracy.

Another method is to use the standard deviation of forecast errors. If the distribution of errors is approximately normal then standard normal deviate tables can be used to indicate the probability of occurrence of errors as multiples of standard deviation about the mean. For example the probabilities of the actual value lying within ± one, two and three standard deviations of the forecast value are approximately .68, .94 and .99 respectively. It can be demonstrated (Trigg (1964)) that for the normal distribution the standard deviation can be approximated to 1.2 x MAD. Thus the MAD calculated at each new forecast could be used to provide an up-to-date accuracy range indicator. (Lewis (1970-a) points out that for other distributions it may be necessary to use 1.3 as the multiplier in conjunction with the appropriate table of distributions).

2.7.0 MANAGERIAL REACTION TO THE FORECASTS

2.7.1 Senior Management Reaction

The set of computer generated forecasts of rivet orders was shown to some of those Managers who were likely to have a use for such information, their reactions were sought during individual interview sessions.

The material presented was a graphical display of simulations covering the period January 1971 - March 1972 showing forecasts for rivets (by metal group) compared with actual requested deliveries (as recorded on the Y.O. file).

The objects of the interviews were:-

(i) To find the subjective reaction of each of the Managers to real forecasts, and to the way they had been displayed.

(ii) To establish if similar forecasts would be of use to them or to find what modifications would be needed to make them useful.

(iii) To establish to what use each Manager thought he would put such information if it was regularly available to him.

(iv) To uncover any previously unconsidered used to which the forecasts (or information derived from the forecasts) could be usefully put.

(v) To ensure that the development of forecasts in content, frequency and layout is directed toward the real needs of the recipients.

The following members of the Company were interviewed: The Assistant Managing Director; the Directors of Marketing and Administration; the Production Manager;

The Production Controller; The Home and Export Sales Managers and the Materials Controller. The main points which were raised are noted below:-

+ Interest was expressed in findings on the percentage of orders placed in advance.
+ Graphical presentation was seen as useful for identifying trends in order patterns and it was pointed out (by the Marketing Director) that if a smoothed average was being used to indicate demand trends, then it was important also to show the actual demand, since a temporary peak in demand could indicate a falsely rising trend for some periods after demand had returned to its normal level.
+ Several people indicated their distrust of existing computerised order load reports.
+ The Administration Director expressed the view that "mathematics in forecasting is not a substitute for but an aid to ..." management's forecasts.
+ It was confirmed that 2 to 3 month forecasts would be needed for the present method of Production Control, but that a shorter horizon could be useful for Assembly, Warehousing and Dispatch.
+ For production the Production Controller would be interested mainly in the product group forecasts but his staff would require a breakdown into individual product.
+ The Production Controller had previously been led to fear, by representatives of the D.P. Department, that if some form of computerised production control system was introduced then some of his present one-sheet 'at-a-glance' status reports would probably

finish up as large multi-page printouts which he felt would be less useful even if the information was accurate. This comment was another indication of the effect of physical report presentation on user attitudes to, and acceptance of, computer systems.

+ Export forecasts should eventually exclude 'sales' to certain countries which comprised inter-company transfers rather than sales to agents.

+ The Materials Controller indicated that sales forecasts would not be sufficient to provide materials forecasts since material usage also depended on production constraints and finished-stock levels. He agreed that the best way to help materials control was thus to provide the Production Office with better forecasts and encourage their use to make better predictions of material required.

General Findings

The forecasts were received with a variety of reactions - from scepticism to enthusiasm. No real hostility was detected at any of the interviews.

A number of people indicated their interest but expressed some reservation due to their lack of firm confidence in some of the computer generated information they already received. This reservation may be attributed to: firstly, a disbelief in the accuracy of information and, secondly, the fact that the present methods of presentation are not conducive to easy perception of relevant information. It seems that there may be some interaction between these two points and that they may sometimes be given as excuses for not understanding the data - though often this is a fault of the system not the user.

These reactions prompted the conclusion that there might be much dormant information, in existing manual and computer systems, which could be more usefully employed if the information display was reappraised in the light of user experience and needs.

2.7.2 Improved Information Presentation - Prompted by the Reactions

At a later stage in the project, after it was realised that inaccuracies in computer collected information would delay the production of useful management information (2.10.0) it was decided to pursue the conclusion (above) on improved information display. During the individual interviews the Marketing Director had expressed interest in the graphic display of Sales patterns and, when approached again, enthusiastically helped both in identifying an area for investigation and in enlisting the help of managers to produce (and use) the information.

As a result the author set up a manual system of graphically displaying, for rivet metal groups and also for industry groups, the monthly sales (and proportion of group to total sales) plus the cumulative year to date sales.

The data is extracted from a manual "incoming order analysis" system (run by the rivet sales office) which was already used to produce similar data but in the form of a monthly table. Since the main objective was to examine the sales pattern of each individual group, rather than to compare group to group (except in two special cases) a separate graph - and supporting data table - is provided for each group. During any one year the previous year's figures will always be visible, and each new month's figures are entered and plotted as they become available.

Although the system has only recently been initiated it has already been acknowledged by the users as a more useful way of receiving this monthly sales information than the previous tables.

2.8.0 DEVELOPING THE REGULAR FORECASTING SYSTEM

Having established suitable methods of forecasting, and re-checked the objectives, it was necessary to set up a pilot system to produce regular forward forecasts to establish if their usefulness was continued in a 'live' situation and to give to users data which they could compare with their own forecasts month by month.

Since the preliminary work had been done with product group forecasts it was decided that they should be the subject of the initial system making provision to extend the system to cater for individual part numbers at a later date.

2.8.1 Data Requirements of the System

The initial forecast simulations had been made using historical data on orders. For the ongoing system it was necessary to have information on

(i) Forward Order Loading - for the next 3, by 4-week, periods,

(ii) Actual Orders - accrued for the last 4-week period.

2.8.2 Capturing the Data

Quarterly YEARSORDERS files, from which historical data had been taken, were accumulated during daily runs of the Order Processing System. This was chosen as the source of 'live information' and was compatable with that already used to establish suitable forecasting methods.

During discussion with the computer operations staff it became clear that this could be most simply achieved by accumulating weekly YEARSORDERS tapes - containing only orders processed in that week - and merging these once a week with the quarterly file.

Besides simplifying the task of analysing incoming orders this also saved computer time since formerly the quarterly tape (of considerable length during the latter part of the quarter) had to be merged once every day, but now had only to be merged weekly.

This weekly YEARSORDERS file would then be shortened to the CONDENSED form as before, to speed subsequent FORTRAN analysis.

2.8.3 Analysing the Data

Two methods of finding forward order load were possible. The first was: prior to each period's forecast, an analysis of <u>all</u> the outstanding orders which would mean repeating the calculations on the same data every time this analysis was carried out.

The second method was to hold a file containing week-by-week totals of the forward orders already placed. Thus each new order would be analysed only once (from the weekly CONDENSED file) and added in to the appropriate weekly total(s). From this file the forward loading patterns required could be computed.

From the results of the previous forward loading analysis (Section 2.6.3) it was clear that only a very small proportion of orders were received more than one year in advance. Thus it was decided to create a file (called FORDORDS) containing 55 weeks of order loading. Of these, 50 weeks would be of forward orders and five weeks of past orders. In this way, requirements for past as well as future data would be met since the sum of weeks 2, 3, 4 and 5 from the file would give the total orders accrued for the last period. (Week 1 was included in case it became necessary at some stage to analyse 5 week periods).

To cater for an expansion of the system into the forecasting of individual products the file was constructed to hold firstly forward orders for each part number, and secondly totals by product group. Each part number/group was entered in a separate record containing 110 items of data, the first 55 referring to Home orders and the second 55 to Export orders.

2.8.4 Initialising the File

To set up the initial orders file a program was written to analyse the YEARSORDERS files for the preceding fifteen months. This established the quantity of orders for delivery over the next 50 weeks and the last 5 weeks and these were written on to FORDORDS file.

2.8.5 Updating the File

Each week new orders from the weekly CONDENSED file had to be combined with existing order totals, and the weekly totals on FORDORDS advanced by one week (so loosing the oldest week).

The program which did this also printed out details of any new part numbers appearing; which gave an indication of logic errors in order details (e.g. 3 deliveries specified but no period between deliveries); it also listed the 50 weeks outstanding order load for each product group.

This last printout was potentially a valuable new piece of management information, even before forecasts had been made from it.

2.8.6 The Regular Forecast Program

This program was designed to produce, once every four weeks, new forecasts for the following three periods on the basis of the latest forward-orders information.

However, it required a further tape file on which to hold, for each product group, details of forecasting method, smoothing constants, forward load proportions, last forecasts, smoothed averages and various error statistics.

A program was written to create and ammend this forecast information file by inputing punched cards, the initialising data being transferred by hand from the printout of the forecast method optimising program. Since there were three forecast periods for each item (one, two and three months ahead), each having its own forecast parameters there was a considerable amount of information to be transferred to the file.

2.8.7 Setting up the System

It was necessary to get most of the programs working before they could each be fully tested since there was much passing of tapes from one program to the next. Having done this the optimising program was re-run on more recent data to give the appropriate 'last values' which would, via the forecast information file, go into the first 'live' forecast.

For each of the ten cases (five product groups by home and export) there were twenty-six items to be extracted from the 'optimised' printout and written onto punching forms.

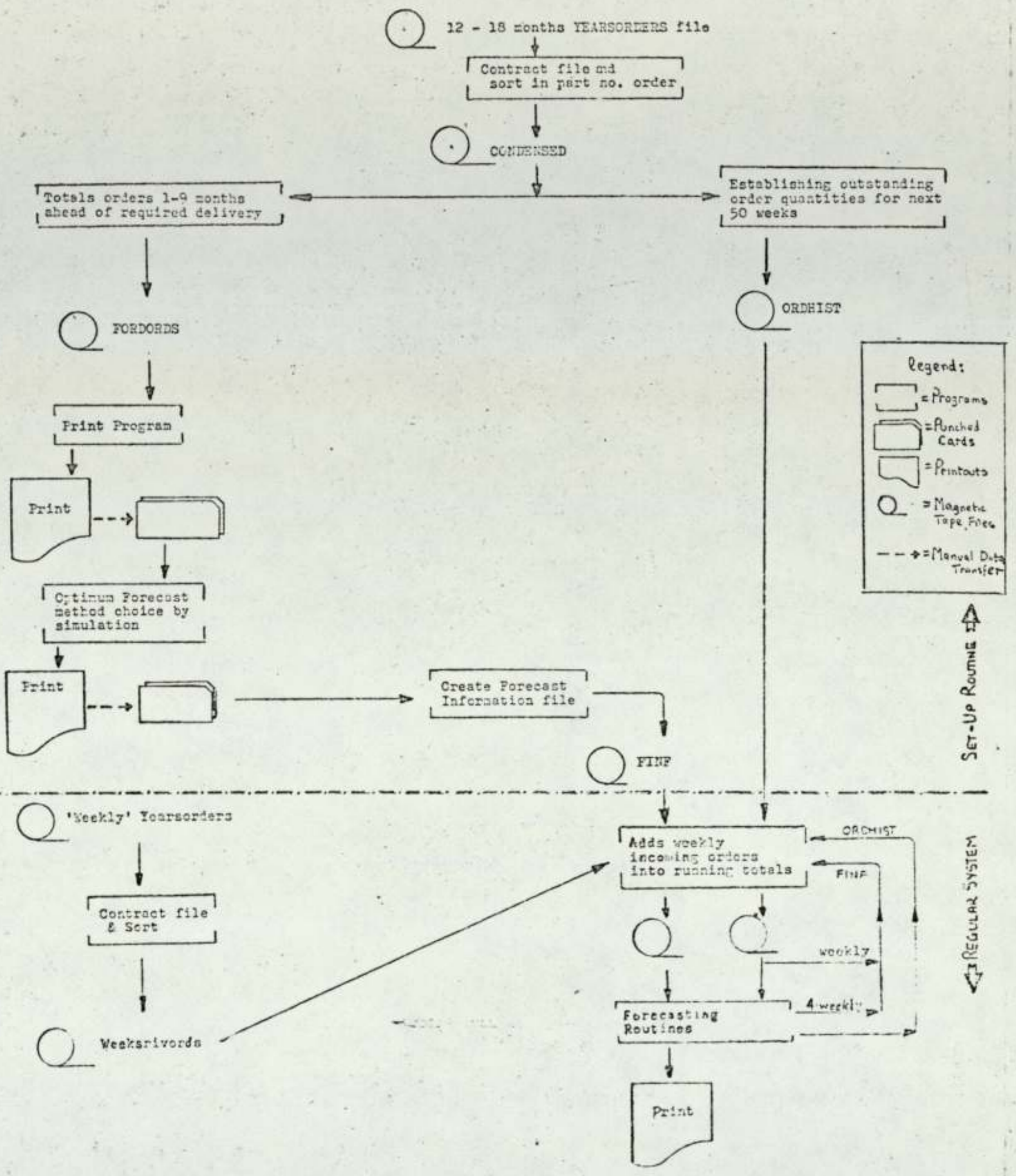
[Carrying out this considerable clerical activity led the writer to realise a useful rule for printout/ document design: ...... if it is necessary to manually seek out a series of data items from one document and write them to another document, then the order in which they appear on the two documents should be the same, and that the layout should, where possible, be in the same sense - e.g. proceeding left to right and/or top to bottom. Even better would be a design whereby a special list (perhaps duplicating information in a scattered layout) be produced, next to which could appear the correct spaces to be filled in on the second document when it was placed on top of, or next to, the source document.]

By the time the initial forecast information tape had been set up and final program development completed, a number of weekly CONDENSED tapes had accrued. Thus the system was 'run-up' from the initial orders tape and two intermediate forecasts produced.

The pilot system, as outlined in Fig. S2, was thus operational.

FIGURE S2

FLOWCHART FOR ORIGINAL FORECAST SYSTEM



2.9.0 SYSTEM INCORPORATING INDIVIDUAL PRODUCT FORECASTS

2.9.1 General Background

As indicated previously one of the system objectives was to provide forecasts of individual products to assist production control.

From a Pareto analysis of rivet sales it was found that approximately 75% of sales (by quantity) were of only 70 products, out of a range of over 1000, so initially it was decided to produce forecasts for these items only.

Experience with setting up the product group forecasts had indicated that even for the ten product groups it was a large clerical task to manually create the forecast information file, and the system was redesigned to remove the slow manual transfer of data from one part to the next.

[In retrospect it would seem that the reason the system had this inefficiency was because of the piecemeal way it had evolved. The forecast optimising program had been designed to produce printouts indicating the forecast precision, but since the rest of the system could not have been designed until it was known what form of forecasts would eventually be used, no provision was made for recording the necessary parameters on magnetic tape. Nor could prior provision have been made for automatically accepting all the required historical order pattern details. Thus it was decided to rectify this by producing such a magnetic tape file.]

Three other features inherited from the piecemeal system were rationalised. First was to combine into one program an analysis of past orders to produce both the historical order pattern and the initial forward order loading file. Second, the forecast optimising program was modified to accept forward load and demand figures direct from magnetic tape. (An additional program was included to edit from the main forward load tape only those part numbers which were required for processing and to set an indicator for those items important enough to have a graph of results printed out). The third feature, was the ammalgamation of the files holding fore-cast data and forward load information. The revised system flowchart is shown on Fig. S3.

Converting the system proved to be a fairly long exercise and once more the author had to carry out much of the program testing and file initialising at night, computer job turn-round having again increased.

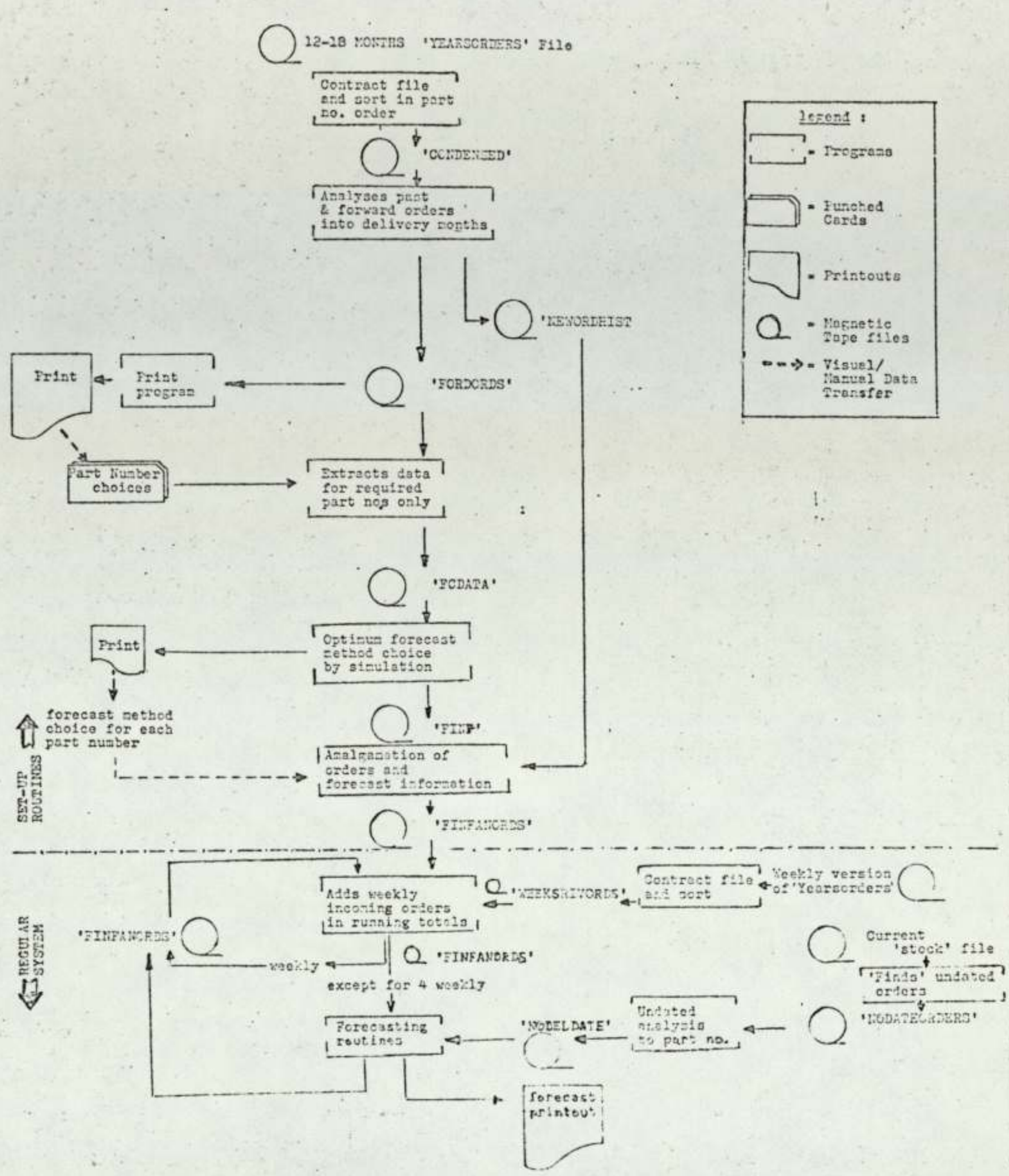
2.9.2 <u>Incorporating Undated Orders</u>

As previously pointed out there is a class of orders for which no delivery date (or an incomplete delivery schedule) is initially specified on the order. The customer then subsequently specifies when all or part of the quantity is to be delivered. This is advantageous for the customer since stock may be held in abeyance for him and also that he can obtain quantity discounts - even if he cancels the balance after one delivery!

Obviously such undated orders cannot be allocated to forecasts for any particular period. It might, however, have been possible to establish some proportion of outstanding undated orders likely to be called-off

FIGURE S3

FLOWCHART FOR REVISED FORECAST SYSTEM



in each period. An initial estimate of the undated sales proportion was derived from the data generated in checking the accuracy of the YEARSORDERS file (Section 24.2). This suggested between 6% and 18% of dispatches were made from undated orders.

To establish this proportion more accurately it was proposed to compare dispatches over a recent 12 week period with the dated orders for that period, the difference being the contribution of undated orders. This contribution would then be calculated as a proportion of the undated orders outstanding at the start of the period.

Since the YEARSORDERS file simply accumulates details of orders there is no indication of when an undated order is no longer 'live', but another file held in the order processing system, called the STOCK file, holds similar data to the Y.O. file and has orders deleted (or outstanding balances reduced) when goods have been dispatched.

Programs were written to analyse this file prior to each regular forecast run, establishing the undated order load for each product and passing the data to the forecasting program, as shown on Fig. S3.

2.10.0 PROBLEM OF DATA ACCURACY

The problems were first encountered when the STOCK file was analysed to find undated orders. The standard software program 'FIND' was used to produce a magnetic tape, in FORTRAN compatible format, containing only those orders with an outstanding undated order balance. This file was then analysed to total these orders by product and product group.

The values were considerably greater than expected and the Sales Manager, when consulted for his opinion, agreed. This prompted the Sales Manager to raise a number of points he had not previously mentioned. He stated that there were likely to be many 'old' orders remaining on the file which had never formally been cancelled (nor thereby deleted from the file) but which the customer no longer required. This would occur if the customer had taken advantage of bulk discount or if he had not scheduled delivery of the remainder of an existing order and had subsequently raised a new one.

It also transpired that some large customers' orders were being raised internally by the sales office in anticipation of their future demand rather than entering real schedules received from customers, so that following a dispatch to one of these customers, details would be fed into the computer to produce an invoice.

When the Manager was quizzed on his reasons for internally raising orders another point was raised upon the completeness of data passing to both the STOCK file and the YEARSORDERS file. It seemed that at the end of 1972 a number of large customers, especially motor manufacturers, had been re-structured with new 'names' at existing delivery addresses. To accommodate this in the order processing system new 'folio' numbers were generated (a code used to identify the customer/address) and associated with all new orders from those customers. There arose at the Company considerable anomalies with orders from the same source now having more than one folio number and in the confusion many orders were ignored or duplicated. Split departmental responsibility has meant that this problem has not yet been resolved.

Since this situation arose the home sales office has not entered details of any large scheduled orders for processing on the computer, thus omitting a valuable portion of forward order loading data from the computer files.

Discovery of this information prompted further investigation which revealed other sources of possible error in the basic data, the search being aided by new documentation on the Order Processing System which had not been available when previously checking the data (Section 2.4.3). Recommendations arising from this investigation are included in Appendix A. Through this investigation it was discovered that order deletions were still being processed without including the relevant order dates despite the author's previous recommendations (Section 2.4.3).

As explained in 2.4.1 the YEARSORDERS file generation had been an addition to the O.P. System. With the aid of the new system documentation it transpired that the YEARSORDERS data was not subject to one fundamental validity check - that the part number ordered really existed. The original system ensured that if the ordered part number had been mispunched the order record would be rejected as having 'no match' on the STOCK file, and the corrected order would be subsequently re-input. Similarly the first orders for a new part number would be rejected until a new STOCK record had been generated. In these two ways the same order might be processed and rejected several times before appearing on the STOCK file. However in the additional part of the system each time an incorrect part number was processed it would appear on the YEARSORDERS file, thus duplicating the order details and creating errors in any subsequent analysis.

Another source of possible error stemming from the accumulation of YEARSORDERS data arises when an error is detected in the order details - perhaps as a result of checking the computer invoice against the original order. The system is not completely rigorous - the invoice may simply be manually corrected and sent off, a deletion and re-creation may be re-processed (with no date for the deleted order) or a new order may be created without any deletion being raised. Any of these points will create inaccuracy in the YEARSORDERS file and possibly also on the STOCK file.

The orders/dispatches comparison proposed in 2.9.2 was carried out in a similar way to the initial checks described in 2.4.2, using dispatch data for February - April 1973 and order data taken from runs of the forecast system. There was a 10-20% discrepancy between the figures for dispatches and orders.

2.11.0 THE FUTURE OF THE SYSTEM

In view of these more recent adverse findings on base data accuracy it was unlikely that the forecast results could be sufficiently meaningful to be used either for production planning or financial reporting until there had been a considerable improvement in the completeness and accuracy of orders recorded by the O.P. System.

Preliminary changes were recommended which would overcome some of the problems but the reactions from the Systems Development and the Management Services Managers were that only the most minor changes could be considered, since they hoped to produce a new order processing system within the next 2 - 3 years. Consequently they decided that there should be no further development of a Sales Forecasting system at least until a new order-processing system is running. The Systems Development Manager indicated that he felt the system currently "produces results which are acceptable to the Company".

The author feels that this statement, and the evidence of the way users were 'manipulating' the system to obtain only what they could trust from it, shows a classic case of the system 'running' the Company rather than the Company using the system to further its best interests. Mason (1971) identifies this, saying that systems "... have within them the potential for freezing an organisation into particular patterns of behaviour long after those patterns have ceased to be valid."

2.12.0 RECOMMENDATIONS FOR FUTURE ACTION

In view of the decision to discontinue development of the forecasting system and the Systems Managers' reluctance to make interim improvements in O.P. accuracy the author has made recommendations to aid the production controllers to produce more accurate forecasts from their existing manually collated data. A report to the Company discussing their present forecasts together with recommendations for improvements appears as Appendix B.

Detailed plans for the new O.P. system have not been drawn up by the Company but it appears that only passing thought has yet been given to provision for generating accurate management information about past and future order patterns. A report to the Company stressing the importance of this provision, outlining a suitable method of order analysis and pointing out possible pitfalls in data collection accuracy is appears as Appendix A.

CHAPTER 3

HARDCOPY INFORMATION DISPLAY

CHAPTER 3

HARDCOPY INFORMATION DISPLAY

INDEX

3.1.0 INTRODUCTION

This chapter attempts to appraise methodically a key factor in successful systems or O.R. implementation - the way in which the generated information is displayed.

The words "information" and "display" will for the purpose of this chapter be taken as meaning : INFORMATION - any piece of data or subject matter, be it numeric, alphabetic or pictorial, which is to be disseminated from some originator to some recipient(s); and DISPLAY - any mode of transference of information from originator to recipient.

Only 'hard copy' displays will be considered.

The subdivisions of this section are not unique and inevitable overlap occurs between them. Nor is the discussion relevant only to systems or O.R. work; much of it applies equally to any displayed information.

An examination is made of the reasons why the information needs to be displayed and defines a taxonomy of the ways in which it is used. A general discussion of the information and its display lists the main types of displays used in O.R. work. This is followed by a more particular discussion on the contents and credibility of the information; the effect of the density and frequency of information on its perceptibility, and the way in which highlighting important features in the display can help in this respect. Graphical display is examined in more detail, followed by specific reference to computer generated displays.

Finally, there are suggestions as to how the many factors discussed can be focussed on the practical task of designing displays.

3.2.0 THE INFORMATION

3.2.1 Why does it need Presenting ?

O.R. or computer system work almost inevitably results in the generation of data or information which affects people other than the originator(s).

To affect them it must first be made known to them (to convey information it must be unknown to the receiver before reception - Hyvarinen (1968). This can sometimes be satisfactorily achieved verbally, but even then it is often useful to permanently record the results.

Of course other social pressures may lead to the information being displayed (even if it is of little use to anyone), such as the originator's motivation to convince others that he has been productively employing his time.

Professor Eilon draws an analogy between physical products and information 'products'. He points out that there must be a demand for information and some ultimate use to justify its manufacture. Jenkins (1972) defines one large source of such demand - 'Management Information' as: "Knowledge, the possession of which enables the Manager to carry out his functions". Thus the information is presented. Is there any way in which separate parts of the information (or its presentation) can be identified for separate study ?

3.2.2 Three Levels of Content

Hyvaarinen (1968) distinguishes three levels within the content of information which usefully identify areas each requiring thought in the design or appraisal of information transmission modes. These are briefly:-

(a) SYNTACTIC LEVEL

The number of possible symbols and their successive arrangement by language or coding.

(b) SEMANTIC LEVEL

The implied understanding of the message being dependant on the receiver understanding the code or language used (".... label or symbol .... always a matter of convention, variable with time or environment and defying the rules of formal logic".)

(c) PRAGMATIC LEVEL

Concerned with the value or utility of information and its strong time dependance (e.g. late receipt of a report may be of little use, whilst some prior information may be very useful). In respect to problem on the semantic level, some attempt has been made to unify the 'language' of O.R. An example of this is the APICS Dictionary of Inventory Control and Production Control Terms (1970).

The symbolic coding (a) and implied understanding (b) of transmitted information can obviously affect its utility (c), but it is important to first understand what that utility is.

3.2.3 What is the Information used for ?

On the Pragmatic level comes the utility or usefulness of the information. Information is used to satisfy a variety of objectives, depending partly on the intent of the originator and more significantly on the motives of the recipient.

The uses to which information is put, can be seen to range from 'active', where direct response to the information is made; to 'Passive' where there is no response directly attributable to the content of the information. Remember it is not generally possible to classify information in this way, but only the use that is made of it; the same piece of information having different significance to different people.

Correspondingly the classification below ranges roughly from active to passive, but the order can not be unique or correct for all circumstances.

The classification covers information in a hard-copy or permanent form. Less permanent recording media would require additional/modified classes.

Any piece of information may fall into several classes, and may lose, gain or change classes with time. The classification may also depend on the frequency with which similar information is received.

A CLASSIFICATION OF INFORMATION USE

Information used for

DECISION MAKING

(i) Quantitative decisions - how much ? how many ?

(ii) Tactical decisions - when ? in which order ?

(iii) Strategic decisions - which approach/method/policy to adopt?

Information used for

ACTION

(i) Following orders or requests from others.

(ii) Emotively prompted by the contents of the information.

(iii) Interactive - action by recipient changes the state which the information recorded.

(iv) As a basis for debate with others (who may have the same or different information)

Information used for

CONFIRMATION

(i) Confirmation sufficient - permanent copy not required.

(ii) Permanent record necessary or potentially useful.

Information used for

REFERENCE

(i) Used at the time then stored for future use.

(ii) Specifically stored for future use.

Information used for

PERSONAL ASSIMILATION (passive acceptance of information without interaction/reaction)

(i) To gain general knowledge and insight.

(ii) To gain particular knowledge.

(iii) To become acquainted with the current state of a system.

Information used for

STATUS/POLITICAL - This may happen consciously, unconsciously or accidentally.

(i) Status of being 'on the circulation'.

(ii) Status of having others ask for the information.

(iii) To impress - having the information 'on the desk' visible to bystander or associates.

Information that is

REJECTED or IGNORED - No reaction or assimilation apart perhaps to discard the document.

- recipient may have no (or think he has no) use for the information.

- recipient may have failed to notice the useful part (to him) of the contents.

3.2.4 Practical Use of the Classification

The literature on displays and information systems contains numerous attempts to classify information from various viewpoints. However, few of the authors indicate specifically how or where their classifications could be of practical benefit. This leaves the reader in a state of suspense to make his own unprompted decision as to how the classification is relevant to his own situation. Under these conditions it is unlikely that he will attempt to put the classification to practical use.

Two uses are proposed for the taxonomy of Information Use as presented in 3.2.3.

The first is in the design of information displays and is dealt with under that title in Section 3.7.1.

The second is in the design of information systems. Haynes, in trying to develop a technique for evaluating management information systems (1970), found that managers had some difficulty in describing the exact use of reports they received. It is suggested that this is partly due to the Manager's difficulty in recalling, during a relatively short interview, all the relevant uses of the information. If the interviewer could accompany the manager for (say) a whole week, situations might well arise which would remind the latter of the more obscure uses. This technique would be protracted, difficult and costly.

To speed up the process of eliciting the Manager's 'uses' it is suggested that, at the interview, he be presented with a version of the 'Usage' Taxonomy (worded in terms familiar to him) as a form of check list to prompt his response. Working through the list to find which class or classes the information does or could fulfil will also be useful in establishing what detailed information the system should generate to make it sufficient for the required use. (Section 3.7.1. outlines some of the necessary information to satisfy each class of usage).

The 'prompting list' could be used either in appraising existing systems or designing new ones.

3.2.5 The Information User

The use to which information is put will, in part, be a function of the recipient's role in the system, and will affect the way in which a display is to designed. Eason (1973) identifies three broad user groups with their degree of discretion to structure their own work as the distinguishing factor. Clerical workers are classed as having low discretion with managers and specialist problem solvers classed high.

Eason finds that clerical workers are more concerned about the ease of reading and use of information rather than its value or accuracy, wheras managers are more concerned if the information is incomplete, inaccurate or clouded by irrelevant information which he has no time to sift through. Thus he points out that it is very important for systems designers to "understand the characteristics of the user whom they wish to serve".

3.3.0 SOME PARTICULAR ASPECTS OF DISPLAY

3.3.1 What Sort of Information does the Display Contain ?

The use each individual recipient makes of a given piece of information depends significantly on his own motives and the context in which it is received. Similarly, these affective factors govern any classification of the 'ingredients' or properties which the display contains. The classification below is thus complementary to that in the previous section.

CLASSIFICATION OF INFORMATION CONSTITUENTS

(i) Introduction to the information (title/summary).

(ii) Basic quantitative or qualitative information for 'raw' consumption.

(iii) Additional information which amplifies points in (ii), if (ii)' basic information motivates the recipient to desire more detail. (This additional information is redundant if he is not so motivated).

(iv) The assumptions which were made in deriving/collecting the information, - this qualifies the data. (If, as is very often the case, these are not rigorously included, then the information is likely to be used outside the bounds of its applicability).

(v) Explanation and definition of terms, symbols or expressions used in the text. (This information is often absent, hidden or implicity assumed and thus can lead to misinterpretation, incomprehensibility and/or non uniform interpretation between different recipients).

The recipient's prior knowledge may make this information redundant.

(vi) Other redundant information which the recipient already knows, does not need to know, or does not want to know.

(vii) Information, though not directly needed is present and serves to increase (or decrease) credibility in the relevant parts. This is often dependent on the recipient's preconceptions of the material, or its source.

It is useful to identify which of the above functions each ingredient of the information fulfils (where possible) as it gives a clue to the relative prominance with which it should be displayed (if at all). More consideration to the layout design is given in Section 3.7.0.

3.3.2 Credibility of the Information

It is easy to understand that if a report or other dissemination of information contains items which the recipient knows or suspects to be incorrect, or in some way based on unsound assumptions, then his acceptance of other items (which may be quite correct but which he is not qualified to question) may be adversely affected. In short the credibility of the whole document will suffer.

In Systems and O.R. work it is frequently necessary to question the decision maker and others in a system, while building a model of it for analysis or reconstruction. This interaction, as Ackoff

(1962) points out, can be usefully employed to gain the confidence of a prospective recipient. Minor points of detail and definition can be informally spotted and rectified at an early stage. Thus, when the final report is received by those whom it will affect, its credibility should not be destroyed by disagreement over minor detail before the essence of the work has been considered. This however becomes more difficult to practice if a large number of people want similar information from the system.

3.3.3 The Effects of Frequency and Density of Information

Psychologists have for some time concerned themselves with the relation between the density of displayed information; the total quantities (or frequency); the recipient's consequent arousal, and his ability to comprehend and use the information.

A study reported by Bickmore et al (1970) on map legibility with increasing information density, fails to reach very positive numerical results but does highlight the fact that individual differences do seem to be significant in determining the information density at which the subject's comprehension becomes 'saturated'. It would therefore seem necessary, when designing systems for unknown future users, to keep the density to a level low enough for all potential users.

In common other cartographical experiments being pursued (e.g. Bartz (1970) this study uses the timed search task to evaluate detection and recognition performance.)

Individual differences make it difficult to determine the saturation frequency of new information. Edenborough (1971) has found that operators responding to a dynamic display, will automatically pace their work according to the incoming frequency, but that extra external pacing may be highly disruptive even on relatively slow internally paced work. Consideration of this point may be useful in designing on-line systems which use tele-typewriters or Visual Displays.

On a more practical level it would seem difficult to appraise quantitatively, in advance, the effects of workload and information density on the recipient's handling of the information. Since many O.R. reports are 'one-offs', they will pose different problems than regularly used systems. However, it is useful to try to make some 'informed' subjective assessment of density and frequency, when preparing information. One way of changing the 'apparent' density without changing the physical density is described below.

3.3.4 Highlighting Relevant Information

Syntactic changes in the form of the information, e.g. highlighting certain items or headings, can considerably affect the Semantics - or implied meaning - of that material. This is especially useful in the case of high density or high frequency information.

The originator of a display will normally have his own concept (consciously or unconsciously) of the class of usage (from 3.2.3 and 3.3.1) into which each piece of information is intended to fall. He may wish to highlight some items (especially title or summary information 3.4.1 (i)) in an endeavour to ensure that the recipient's classification coincides more nearly with his own intentions, and hence increase the chance of uniform interpretation. There are many techniques for achieving this - from simple underlining or the use of special typographic forms, to overall plans for the organisation of categories of information.

Typographic Highlighting

Some experimental results, useful when considering typographic form, were recorded by Bartz (1970). Subjects were given a list of six place names and were asked to find them on a map containing many names. Time taken to search out the six was measured for (a) uniform type-face for all the map, repeated for various type-faces; (b) mixed type-face, but where the searcher did not know in which form his names would appear, and (c) as for (b) but where the searcher knew in advance the type-face of the names for which he searched.

Results for (a) showed no significant difference between kinds of type-face; for (b) the results were generally slower than for (a) but for (c) there was a dramatic reduction in search time, (up to as much as 70% below the same map as (b) for distinctly contrasting type-faces). In the report this is attributed to the fact that the preliminary perceptual-cognitive process, which separates the map into 'relevant' and 'irrelevant' targets, takes very little time compared with the decision wether or not a particular name being examined is the target name.

Grouping by typographic form could be used where two or more people must extract different information from a single document,but would be limited for computer print-out with its restricted character set.

Thus the use of anticipation in 'highlighting' can be a useful and powerful tool. However, anticipation can lead to mis-interpretation if the display differs from the recipient's expectation. An example of this is the way in which graph scales can be expanded or compressed, to change the <u>shape</u> of the plot.

<u>Categorisation of Information</u>

The organisation of categories of information has received much attention in the development of self-instructional books, and the organisation of data bases for computer aided instruction and reference. Horn, et al (1969) presents a method of 'Information Mapping'. Information is presented in blocks, separated by horizontal lines. Marginal labels identify the kind of information in the block, and all similar types of information follow a consistent format. It is recommended that 'map' headings in consistent typography help in scanning for page topic, (presumably this is another example of aid by anticipation) and that the marginal labels help both in locating wanted details and skipping unwanted. As important as the physical layout are the principles used to select and organise the content. Their report considers this from various viewpoints.

So it is clear that the way information is organised and presented can have a considerable effect on its impact; aiding the originator to ensure uniformity of interpretation and helping the recipient to glean from it more easily what he needs to know. Conversely, ambiguity or unintentional inferences in presentation can drastically alter or distort the meaning of the information presented.

3.4.0 EXISTING O.R. DISPLAY TECHNIQUES

Looking more specifically to O.R. generated informations; what forms of display are currently being used. Below are some of the forms and their applications.

3.4.1 Numeric Tables

(In line; single or multi-column or matrix form).

These may be used for conveying quantitative information. The exact form will depend on the type of information (e.g. single row or column table for listing possible outcomes of a situation given that certain actions are taken; or matrix table if each outcome depends on two independent actions.)

Tables/matrixes are also useful for setting down the steps of an itterative calculation carried out by hand, or the preparation of data prior to computer solution.

Discussion of Numeric vs. Graphic representation is made in section 3.5.4.

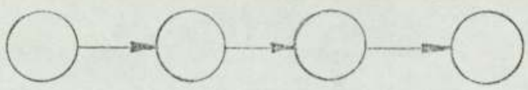
3.4.2 Network Diagrams

Network diagrams occur frequently, in many guises, in O.R. work.

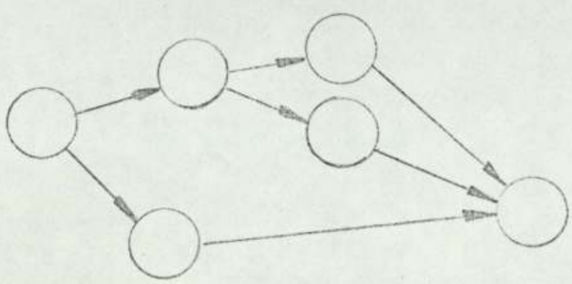
Stochastic Networks show the association between connected events with their associated probabilities of occurrence.

PERT Charts or Critical Path Diagrams are also a form of network diagram, showing sequential occurence of events which must occur to achieve a prescribed end condition. The charts are used either as a visual aid to project planning and control, or as an aid to the solution of the critical path problem. PERT and critical path charts are widely used and have fortunately a reasonably consistent and widely accepted 'language'.

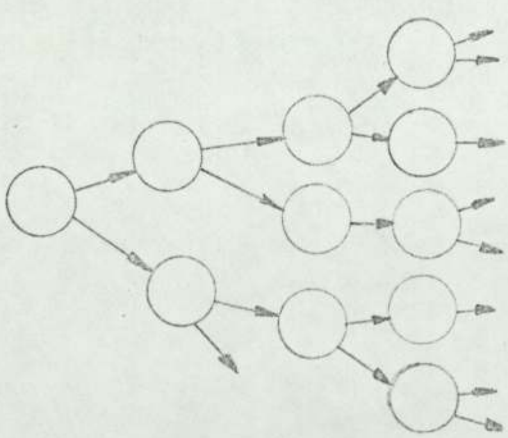
Network diagrams may occur in serial, directed acyclic or divergent 'Branching tree' forms, as illustrated below :-



Serial Network



Directed Acyclic Network



'Branching Tree' Network

3.4.3 Flowcharts and Block Diagrams

These are forms of network diagrams but are used normally to chart interrelations between functions in a system. On block diagrams arrowed lines connect the 'boxes' of information, which describe the functions of each part, with the lines showing the interaction paths. On flowcharts the boxes are used to describe the interaction paths and the lines labelled to name the functions so connected.

Block diagrams are frequently used in O.R. work for constructing conceptual system models for analysis.

Mason (1971) identifies a danger in setting up Management Information systems which also applies in constructing conceptual or factual flow-charts to define systems. He says that they ".... have within them potential for freezing an organisation into particular patterns of behaviour long after those patterns have ceased to be valid."

3.4.4 Schematic Diagrams

This type of diagram is included here for completeness but is not frequently used in O.R. They are diagrams used normally to describe hardware 'pictorially'.

3.4.5. 'Visual Aid' Displays

Techniques such as flip charts, overhead projectors and slide projectors are widely recommended for presenting O.R. material to live audiences; the method used, and the control, depending on the size and the background of the audience. Ackoff (1967) makes some recommendations about their use.

3.4.6 Written Reports

Report writing has received much attention from people of many disciplines, and numerous recommendations as to report layout and content have been published. Among the more innovative of these are the methods of Information Mapping. (Horn et al (1969)).

Again Ackoff and Sasseini (1968) give guidelines on report presentation, but even their remarks are not specific to O.R. reporting.

Reports on O.R. work usually contain numerous tables, graphs and diagrams which serve to illustrate the text. The addage 'one picture is worth a thousand words' is probably true in O.R. but little has been formally set down about the interaction between the elements. One such example is by Rasmussen (1971) who describes how in a power supply control system, operators use . graphs for a 'feel' of what was happening and referre to tabulated data when they require exact values.

3.4.7 Progress Charts

Various forms of charts and graphs are used to show progress towards, or deviation from, some objective; to just display past and regularly updated current states of some parameters of interest; or (loosely embraced under this heading) to trace the location of some mobile entity of interest. The GANTT Chart is an example of the first type, showing graphically planned performance and actual progress by horizontal lines of length proportional to progress.

3.4.8 Graphical Displays

Graphs are a widely used form of communicating information, and in many cases the most meaningful way of doing so. This latter fact, although generally agreed with, has received little formal acclamation. (One recommendation from the education field comes from Feldman (1965)), Rarely does it occur to authors to record the effectiveness of their information display, when reporting the effectiveness of the implementation of a system. One such exception by Curley et al (1967) presents a table of Return on Investment (ROI) vs. the probability of equalling or exceeding this ROI; then plots this as a probability Ogive. Their favourable comment on this latter presentation is that they ".... have found this to be an expecially effective way of communicating the meaning of cumulative probability distribution to the decision maker. .... the manager is provided with a composite, easy to understand graphic display of his risk."

This kind of comment shows a subjective recognition of the usefulness of graphical display.

Graphical presentation is further discussed in Section 3.5.0

3.5.0 GRAPHICAL INFORMATION DISPLAY

As has been shown in section 3.4.8 graphs are recognised as being useful in lucidating certain information. Ackoff (1962) tells us that research results should be presented to the audience "in their own language". The author has found that graphical displays can serve as such an interface for presenting an intermediate 'language' between technical 'jargon' and the understanding of the layman.

The main disadvantage of graph display is the cost of producing it and this must be considered when deciding on the form a new display should take.

3.5.1 What do graphs display well ?

Graphs are generally used to display a range of data values. The independent variable usually being time, quantity or frequency; with quantity, frequency or probability for dependent variables. They allow a direct visual comparison of one point with another, using the observer's intuitive category breakdown (Miller (1963) with clues from the printed scales). The human mind is well suited (in most instances) to interpolate or extrapolate the pattern of a graph; being able to carry out mental integration and differentiation without resort to slow serial thinking, to which he might be reduced if faced with a tabular list of values.

A lucid example of graph display of an O.R. type problem occurs in Forrester's book (1961) on Industrial Dynamics, where he plots changes in demand, orders and stocks as a function of time, and clearly illustrates the meaning of 'damping' and 'instability' in the context of an industrial system.

Jervis (1971) says "The main incentive for graphical displays is to show trends.... Absolute accuracy is a secondary consideration, because it can be provided by numerical data" and Bainbridge (1971) says ".... evidence suggests that....decisions actually make use of rough estimates of the data values"; thus it would seem that pattern recognition and extrapolation/interpolation functions are the fundamentally important uses of graphical displays.

3.5.2 Interpretation of Graphical Displays

The recognition of patterns has interested many psychologists and ergonomists, but frequently their work does not produce much in the way of practically useful results.

One aspect of interpretation is the inate human capacity for visual judgement. There is always a danger of confusion from optical illusions, or unexpected and ambiguous format, which must be avoided if possible. But this apart, it is possible to identify that people can subdivide relative magnitudes into a number of categories. Miller (1963) finds that between 5 and 9 categories can be distinguished. Easterby (1970) summarises work by Mackie, who found that small sets of symbols impose no severe load on perception but larger sets of symbols are difficult to remember.

Trend identification can be an important factor in O.R. work, especially in the techniques of manual forecasting. Schutz (A) (1961) has done work on the best display form for human accuracy of judgement and he found that for visually identifying trends a line graph is best, followed closely by vertical bars and lastly horizontal bars. He also found that missing or irrelevant points greatly degradated trend identification.

Results of conventional mathematical analyses can sometimes usefully be combined with these manually identified patterns to form more accurate final solutions.

A way of combining such results is discussed in the section 26.5.

3.5.3 Graphical Solution Techniques

Increasing use is being made of graphical solution techniques in the solution of O.R. problems. These are cases where the O.R. man is effectively displaying the information to himself in order to perceive the solution; to guide his choice of direction of a more rigorous solution search; or allow a deeper understanding of the problem, that he may himself derive new solution techniques.

A few examples of applied graphical solutions are listed below, but are not expanded on. Numerous other applications are reported in O.R. literature.

Examples:

(i) Use of flowgraphs to represent and analyse a set of simultaneous linear equations - Lorens (1966).

(ii) Graphical display in resource allocation Cloot et al (1969).

(iii) Various extremal problems - duality - travelling salesman problem - satisfying constraints - network problems - Yu. M. Ermolev et al (1969).

(iv) Machine sequencing by disjunctive graphs - generates a sequence of circuit free graphs, solves the critical path for each, then improves the schedule. E. Balac (1969).

3.5.4 Graphical vs Numeric Display

Graphical displays can only be used to represent one, two, or at most, three 'dimensional' information. To display higher order dimensions (such as with a multi-variable linear programming task) some form of tabular or matrix layout must be used.

However in areas where the two methods are alternatives, which is better ?.

Vernon (1952) finds that a different interpretation of 'greatest change' is made from the same data when presented in graphical or table form. Subjects chose the items with steepest slope from the graph, but items with the greatest percentage change from the table. However, much of Vernon's work is suspect because the subjects she used generally had little or no experience of graphs (and by her own admission performed poorly compared to more skilled subjects). Questions were asked as to what people remembered, and whereas this second point may have particular relevance in the learning field, for the O.R. situation, a subject will normally have continuous visual availability of the information display.

Pollack (1971) sounds a more hopeful note for the usefulness of graphical presentation. He says "People are often able to appreciate extremely complicated masses of information after encoding in the form of visual displays....understanding is often aided by - indeed understanding often requires - a concrete visual representation". Even so Singleton estimates that approximately 10% of people do still prefer a table of numbers to a graphic display.

Standard psychometric tests exist for distinguishing these 'numerate' thinkers from the 'spatial thinkers' and it might be useful to apply them to a decision maker before loading him up with a desk full of graphs.

However, there is not always a conflict between the two forms. Their functions may be complementary as found by Rasmussen (1971) , and Vernon (1952) found it was, in any case, necessary to provide a certain minimum amount of alpha-numeric information to explain the graph.

Statistical analysis generates large quantities of numeric information. However, even the numeric ate statisticians find it useful to display many of their results graphically.

3.6.0 COMPUTER DISPLAY OF INFORMATION

Computers and computer print-outs often act as the interface between management information systems and their users. Indeed in many commercial spheres the two have become (wrongly) synonimous - other channels of communication being forgotten.

What are some of the advantages or disadvantages of this display medium ?

The credibility of such output can quickly suffer if incorrect data has been prepared for the computer and the result has been seen to be erroneous. This danger is probably greater with computer generated material than human generated. The reason for this is probably a complex combination of human prejudices, emotions and pre-conceptions.

On the semantic level, computer output often isn't designed to bear any detailed definition of the terms used. (For instance the formula used to compute the values shown). Also the originator being (or seeming) more remote to the recipient, the latter is more likely to 'muddle along' thinking he understands, rather than quizing the former. This may not matter too much when the system is first set up; the user may even have defined the equations to be used. But what of the other users or replacement personnel who were not involved in the design, and who probably haven't been circulated with instructions for interpreting the display output ?

Computer generation can save a great deal of time in producing displays, even if only a line printer, with its limited character set, is available. Forrester (1961) lucidly uses a line printer to plot graphs of complex industrial interactions.

Many of the design suggestions in section 3.70 are applicable to the design of computer print-outs.

3.7.0 THE PRACTICAL DESIGN OF DISPLAYS

As pointed out in the introduction,this Chapter is aimed primarily at the hardcopy display of information. Other forms - V.D.U., audio and machine linked displays need consideration of additional ergonomic and human factors.

From the discussion in previous sections it is apparent that the way in which information is displayed has a significant effect on its interpretation and usefulness. Thus careful design is essential. Eilon considers information as a product which, like a physical product, needs specifications (i.e. the detail and accuracy required of it and the format in which it should be presented).

This section focusses the points previously discussed (and others) onto the practical design problem. Since there are so many (often conflicting) criteria there is still a considerable part to be played by the human designer.

It is he who must ultimately classify the constituents and strike the best design compromise between all the constraining factors.

3.7.1 Contents of the Information

Section 3.2.3 contains a taxonomy of Information usage. It is possible to identify in general terms, for each class in the taxonomy, certain basic elements of information which should be present to enable the information to meet the user's requirements. In any particular context more (or possibly less) elements may be needed (or sufficient). The system/display designer can compile a list, based on that below for his own particular application.

INFORMATION ELEMENTS REQUIRED
FOR PARTICULAR USES

(IN GENERAL TERMS)

For

DECISION MAKING

+ Quantitative data -either 'raw' or as the result of analysis
+ Information on alternatives and their likely consequences
+ Information about the present and predicted future state of the environment
+ Information about constraints from within the organisation
+ Qualification of the data
  - assumptions
  - time scale over which data still valid.
  - definitions
  - expected accuracy (especially for probabilistic data)

For

ACTION

+ Unambiguous description of the action required (if action is specifically required).
+ Interactive 'driving seat' situations require fast and/or regular feedback of information about the present status of the system variables, and cues as to the rates and direction of change of these variables. ("It is not status information per se, but the predictive value of status information that the operator requires for effective ... feedback control" -Kelley (1972))

For

CONFIRMATION

+ Information or data being confirmed
+ Date/time on which it was true/occurred
+ Basis on which it was derived
+ Time after which it will no longer be true/valid
+ Source of confirmation (Person, department or whatever)
+ Information conforming to user's system of filing (if known) for permanent record copies.

For

REFERENCE

As for confirmation information

- Layout for easy identification of document - by coding system of prominent description heading, as appropriate to the application. Cross reference to other relevant information.

For

PERSONAL ASSIMILATION

+ Main ideas and general description

+ Greater detail on some or all points.

For

STATUS/POLITICAL

+ Limited circulation

+ Contents dependant on situation

to be

REJECTED/IGNORED

+ Originator is not usually aiming at this usage but can help recipient to make the correct reject/ accept decision more quickly by summarising main points briefly and prominently.

USING THE CLASSIFICATION OF INFORMATION CONSTITUENTS

Section 3.3.1 outlined 7 classes of information constituents, ranging from particular and summary information to redundant contents. It is useful for the designer to classify in a similar way, the parts of the information he wishes to display. This will help him in deciding the relative prominence with which each part should be displayed, and also to identify parts omitted or surplus.

BEWARE OF OMISSIONS : The designer should be very wary of omitting any part which fulfils (or could fulfil) the functions (iv) and (v) in 3.3.1 (i.e. Assumptions, Qualifications and Definitions of terms and expressions). Ensuring that the presentation is 'complete' in this respect requires a careful conscious appraisal both before and after the display design.

Parry (1967) identifies the 'Unstated Assumption' as one of a number of Barriers to Communication. He says that "The commonest source of everyday misunderstanding originates in the speaker or writer making an assumption which he thinks it unnecessary to render explicit...This barrier is essentially of a cognitive character...(i.e.) failure is due to ignorance or lack of information on the receiver's part".

As has been pointed out by Eason, managers are unlikely to admit to having information around just "to impress" (STATUS/POLITICAL CLASSIFICATION) but it is probably for the designer to bear it in mind as a use to which the information may be put.

ALLOWING FOR TASK EXPANSION

Singleton (A) points out that since the recipient can change his strategies or goals he needs the data which will enable him do so if required and, ... Since these changes are not easily forseeable the display presentation must be sufficiently comprehensive to allow the operator to cope with situations which the designer never predicted."

This implies a certain redundancy of information which, in the case of commercial systems may be difficult for the user (recipient) to accept. Where such redundant information is presented it is therefore important that its presence does not overshadow or detract from the more immediately useful contents.

ABSENCE OF COMMUNICATION CHANNELS

Parry (1967) pinpoints this as one of the 'Barriers to Communication'. As a result of a number of accidental observations the author feels that this barrier is often not appreciated even by those closely involved with the situation.

The designer of a display should be aware of the general information system into which his display will fit. By considering whether possible communication channels in that system are absent (or ineffective) he may be able to improve the system and thus - directly or indirectly - improve the effectiveness of that display he is designing.

The author has found that one method of doing this is to list each distinct organisational section as an 'information centre'. A brief task analysis is carried out for each centre, listing information requirements (sinks) and information that could be generated by that centre (sources). Comparing all these information sources and sinks (a flowchart with info. centres at the nodes is useful) soon shows where strong communication channels should exist. Where in such cases a formal channel is not found an informal one is often functioning, and the author feels that this may often be the reason why such informal channels are seen to play an important part in the running of an organisation.

3.7.2 PHYSICAL LAYOUT

There are many different factors for the designer to optimise, and it is difficult to lay down positive design rules. However below are discussed some principles which can be usefully considered.

Strings of Numbers & Column Grouping

Long strings of numbers can be difficult to read and copy accurately. Conrad and Hull (1969) experimenting with time and accuracy of dialing and keying trains of 12 digit telephone numbers found that it is best to visually break the chain up into equal length groups of 2, 3 (best) or 4 digits.

Thus for many applications breaking up a string of digits into multiples of 1000 (i.e. groups of 3) is a good way to improve legibility and accuracy.

The visual breakdown of the string may be achieved by several methods; intergroup spaces; different coloured background blocks for each group ; separation by punctuation marks; or bolder interblock division lines (e.g. for computer punching documents where each character has its own 'box').

Tinker (1960) reports that within columns of items it was helpful to group items in blocks of five rather than blocks of ten, but that blocks of ten were better than no blocks at all. He also found that ruled lines appeared to be as effective as spaces for marking distinctions between columns but the author has observed that unless lines are used to separate column headings/ titles there is a danger that adjacent titles will be incorrectly read as one heading - e.g.

STANDARD ERROR	DEVIATION IN MEASUREMENT	vs.	STANDARD ERROR	DEVIATION IN MEASUREMENT
XXXX	XXXXXXX		XXXXX	XXXXX
::::	:::::::		:::::	:::::

Dividing Lines on computer printouts can easily be printed by choice of appropriate symbols.

Contiguity (Proximity) of Information Elements

The GESTALT laws of perception formalise a common sense idea that two related objects are best perceived if close together in time or space.

This principle is relevant to the design of displays in that if two or more numbers or items of information are to be compared they are best sited close together on the document. If the comparison is to be made between two separate documents (perhaps from different sources or produced at different times) then it may be possible to format the two documents such that they may be layed side by side or overlapping to bring the required figures close together.

If the requirement is for say computer generated figures to be compared with manual recordings - then perhaps the computer can be provided with spaces adjacent to the computer figures into which the manual figures can be recorded directly. This idea similarly applies to non computer documents.

Watkins (1970) points out that if a piece of information is used separately in conjunction with several other items on a scattered display then it may be usefull to repeat the multi purpose item close to each of these other items. He also points out that if the recipient's taks must follow a pre-defined sequence then the information should be presented serially in the order required.

Wright & Fox report the common observation that when there is a large gap between the item to be looked up in the table and the information to be read off then it is easy for the eye to misalign the two columns and read off information directly above or below that required. Tinker (1960) attributed to this the beneficial effect of grouping items within columns.

Vertical vs. Horizontal Character Display

Coffey (1961) found no significant differences in subjects performance in scanning tests of characters displayed first horizontally and second vertically.

Williams (1966) however, with a more practical test requiring the subjects to read groups of characters and compare them, found that subjects could identify discrepancies between pairs of 3 digits numbers, 60% faster if arranged horizontally e.g.

323 than if they were arranged vertically 3
2
3

333   3
3
3

The author feels that a weakness of this test is that it did not try comparison in the 3 3 form, where compared
2 3
3 3

digits are in closer proximity but does demonstrate that contiguity is an important factor.

THUS IT WOULD APPEAR THAT WHERE POSSIBLE THE ACTUAL DIGITS TO BE COMPARED SHOULD BE ADJACENT TO EACH OTHER.

Holly and Nuismer (1972) found that words arranged vertically could be recognised far better if they had frequently been encountered in this form before e.g. H
O
T
E
L

Since this will not often be the case in specialised displays it would seem inadvisable to use this form for 'occasional' users, but 'regular' recipients of the display will learn to recognise it more easily.

Highlighting

A document covered with writing or printing, and having no part which unconsciously compels the recipient to read that part first, can have an effect on the recipient like that of a monotonic speaker. However good is the material being presented the recipient is not motivated to give his best attention. It is left to him to place his own emphasis - if he can be bothered - and these may well not correspond to the originator's intended main points.

Thus it is usefull to define a hierarchy in the elements of the information (as in section 3.3.1) and to accord them relative prominence commensurate with their importance.

Usually the title, summary and important key words can be highlighted in different type face, colour or size; perhaps underlined, set aside from the body of the information by a space, or by enclosure in a lined box (see 3.3.4). This will enable the recipient to quickly establish what a new document contains and if it is of further interest to him.

Singleton points out that the recipient is rarely restricted for long to one task defined by one display. Hence the designer must allow for the recipient frequently changing from one display to another. If a recipient receives a number of otherwise similar looking documents (e.g. computer printouts) it is useful to him if they each have some distinctive (highlighted) feature, for example to distinguish between measurement units used.

In other cases where the recipient regularly receives the same document, highlighted headings to subgroups may be more useful to him than the main title with which he is already familiar.

If the display is a form to be completed manually then any special instructions should be boldly highlighted, especially for unfrequent users.

Anticipation

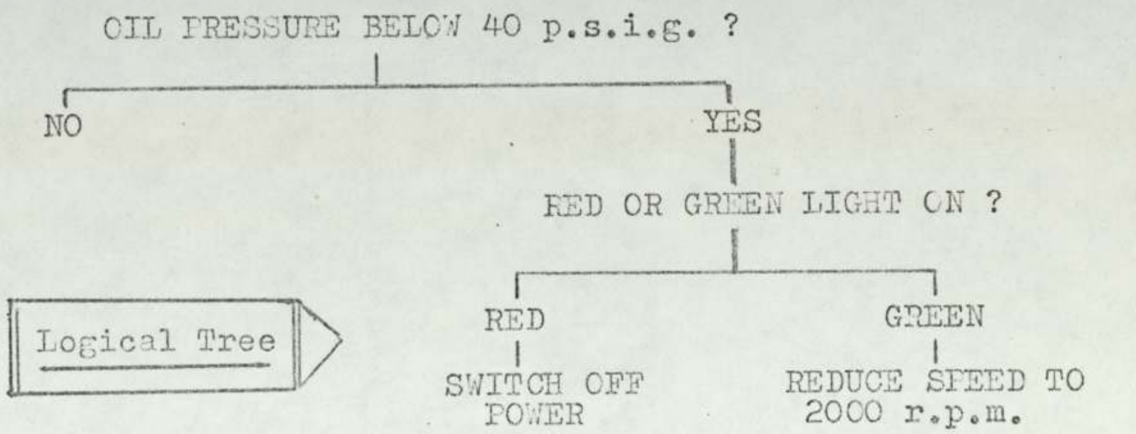
As reported in section 3.3.4 it has been found that a subject scanning a set of information which contains several sorts of highlighting (e.g. type-face) can very rapidly skip over any items not in the particular form in which he anticipates he will find the items he seeks.

Use of this technique could enable the same document to be used by two different recipients, each reading only that part presented in their own (expected) form. This would not work so well for computer printout where (normally) typeface is of one type only - however the different parts could be identified by markers, e.g. an asterisk next to all headings relevant to one user (or use).

Another way in which anticipation can aid the usefulness of a display is by ensuring that a new display is, if possible, compatable with the form of display which the recipient is already receiving (if any).

Why use Sentences ?

Wright (1971) says "Recent studies have shown that abandoning the prose format for alternatives such as logical trees and tabulated presentations can often improve comprehension". The following are examples of the latter two presentation forms.



Two-Dimensional Table

	RED LIGHT ON	GREEN LIGHT ON
OIL PRESSURE BELOW 40 psig	SWITCH OFF POWER	REDUCE SPEED TO 2000 RPM

Jones (1968) also finds that these two forms are more accurately and quickly used than prose when applied to the drafting and interpretation of rules & regulations.

Wright and Reid find that a table form is best if the user is fairly familiar with the problem area but that a logical tree is more helpful to those unfamiliar with the area and who need help in finding the relevant part of the information.

However for information which is to be used many times, a series of short sentences are more easily remembered than either tree or table.

They also advocate the use of labeled diagrams to avoid confusion over jargon, e.g. "(1) Check this angle" (arrowed to diagram); "(2) Loosen this nut" (arrowed to diagram).

Logic of Tabular Structure

There are a number of ways in which tables can be laid out, to suit the complexity, quantity and end-use of the information. Wright and Fox (1970) refer to two main types - firstly EXPLICIT tables, which contain the complete set of required information and in which the user need only search for the particular item he requires (e.g. a book's index of chapter headings and sub-headings) - and secondly IMPLICIT tables where the user must perform some function of interpolation or addition to obtain the value he requires (e.g. Logarithmic tables or a decimal currency conversion table showing only the conversion for integral numbers of shillings plus the conversion of old to new pence within one shilling).

Explicit tables may be constructed either as a list of possibilities or, for more complex information, in a matrix form - such as often used for charts of mileage between towns. Wright and Fox discovered that the matrix table was uninteligible to some people, even after careful instruction, and concluded that it may be a mistake to adopt such a table for use by the general public, and that a one dimensional explicit tabulation was the only viable method for such cases.

Graphical Display

Some of the techniques already mentioned (such as highlighting) can be applied in the design of graph layouts, but there are some useful rules specific to that purpose - as outlined below.

Scale Markings

+ Limit the scale divisions to the accuracy required [(1)]
+ Numbered graduations should increase by units of 1, 2 or 5 units (or decimal multiples of)[(1)]
+ No more than 9 intermediate scale points between numbered divisions [(1)]
+ Construct numbered bolder (and/or longer) than un-numbered and if 9 intermediate points are used the 5th line should be less bold than the numbered but bolder than the remaining un-numbered.[(2)]
+ Increases in magnitude of scales normally left to right and bottom to top.[(1)]
+ Wherever possible arrange zero points of scales at their intersection ('origin') to avoid confusion and where not possible highlight the values of the non zero origin.[(author)]

---

(1) Barmack & Sinaiko (1966)

(2) Baker & Grether (1954)

Point and Line Plotting

+ Line graphs are best for plotting trends (3)
+ Where discrete points are being plotted, these should be clearly differentiated from the joining lines (author)
+ If a number of plots are to be compared then it is better to plot them on the same graph than each on individual graphs (4), but if this is not possible then individual graphs should have identical scale sizes and markings. (author)
+ On Multi-line graphs colour can be used to differentiate between the lines, but if this is not practicable (or economic) the following symbolic identifiers have been found to give low confusability. (4)

```
+-----+-----+-----+--
---o-----o-----o---
-A-----A-----A----
●ooooo●oooooo●oooooo●ooooo
```

+ On graphs used to identify trends missing or irrelevant points can considerably degrade interpretation. (3)

Ancilliary Information

+ Wherever possible the graph should be self explanatory requiring the minimum of reference to any accompanying text.

---

(3) Schutz (A) (1961)

(4) Schutz (B) (1961)

Typographical Considerations

Much has been written about the effect of typography (i.e. the style of printing) on the speed and accuracy of comprehension of printed material and some of the main findings are summarised below.

+ For often refering to information 8-10 point type size is best (72 points = 1") but smaller sizes can be used for infrequently used references (Watkins 1970).
+ Sentences of all-capital letters are less legible than lower case or mixed characters (Watkins - also Patterson & Tinker 1940).
+ Line lengths of approx. 30 characters gave fastest reading speed in the range of 10-50 char/line as tested (Lewis R.A. 1972).

General Physical Considerations

Some simple physical constraints should be considered early in the design of a display. Being so simple they are often overlooked and the resultant display - however good in itself becomes second rate in use.

For example : Is the document going to be folded ?. Plan for this. Perhaps users will often only be refer ing to a part of the information; can this all be put on the exposed (when folded) face, together with the title ?.

+ Avoid printing characters on or close to a fold, since they may be obscured by the fold or obliterated by repeated folding (Watkins 1970).
+ Will the document be bound or clipped together with others or have holes punched for loose leaf filling ?

Allow space for the fixing/punching; and leave sufficient margin that no part is obscured when the documents are tightly bound.

+ Will the document be frequently sought from a pile or file ?

Place a code or title on the same corner of all documents in the file for easy 'flick through' reference. (This should be the top right hand corner to satisfy the population stereotype but depends otherwise on the geometry of the filing system).

British Standards

There are a number of British Standards relating to various aspects of display design, a useful summary of which is given by Whittfield (1971).

3.7.3 RETROSPECTIVE CHECKING OF THE DESIGN

A Check List

Singleton (B) (1969) insits that there is always the possibility that some important facet will be omitted and suggests that a checklist is a valuable safeguard. Below are the relevant parts of Singleton's checklist for hardcopy display design. It is organised with the assumption that a logical series of checks should relate to necessity, sufficiency, legibility and compatibility.

INFORMATION DISPLAY DESIGN CHOCKLIST

	POSSIBLE OBJECTIVES	PARAMETERS, TECHNIQUES AND PRINCIPLES
Necessity: Does the user's need justify the provision?	Is it worth the expense and the complication?	Cost effectiveness studies
	Can the user manage as well or better without it?	Justification other than on the grounds of information: tradition apparent quality styling
	What happens if it is incorrect?	Critical incident studies possibilities: no information presented false information presented
Sufficiency: What data may the user need which has not been provided?	Would more data be useful: as routine? to set up or change the system? in case of errors? about past state? present state? future state?	Task Analysis
Legibility: Can a user with average senses see, easily, what is required?	Is the presentation about the right strength	Visual parameters: position size orientation lettering size style excess scale division graduation clutter
	Is it clear where the data are available. Is it clear what the presented data are about.	Connections with real events: physical symbolic legends
	Have unnecessary data been eliminated?	
Compatability: to other display items?	Is the accuracy appropriate in terms of: acceptance perception	Error summation studies
	Have the most appropriate grouping and highlighting principles been followed?	Possible grouping principles priority frequency of use similarity or identity of function
	Have the most appropriate grouping cues been used?	Possible grouping cues: colour shape size position
With previous habits and skills?	Will the user require special training?	Skills analysis
	Is there likely to be a discontinuity with earlier operator experience?	Population stereotypes
With required actions and decisions?	Does the presentation encourage the user to: think about the right problem in the right way? select the right action?	Encoding to match perceptual models

APPENDIX A

CONSIDERATIONS IN DESIGNING A NEW ORDER PROCESSING SYSTEM

APPENDIX A.

Considerations in Designing a new O.P. System

A.1. DISCUSSION

It has been proposed by the Company's System's Development Committee that a new Order Processing (O.P.) system be developed, both to improve on the accuracy of the present system and to streamline data input and computer processing. This latter aspect is receiving much attention from the Management Services department with the introduction of on-line order entry through VDU terminal. The provision of various 'commercial' outputs (such as invoices and advice notes) has also received attention, but there has so far been little consideration of the valuable management information which could easily be produced by the system if it holds accurate details of all orders received by the Company.

The writer has established that data from the existing O.P. system is not adequate to provide usefully accurate sales forecasts and is anxious that this situation should not recur. A number of the points arising from the sales forecast investigation should be considered when designing the new O.P. system. This report outlines these observations and it is emphasised that if they are not seriously considered in developing the new O.P. system then its potential usefulness to the Company is not likely to be fully realised.

It is expected that by producing more useful and accurate management information to be used throughout the Company that the users will have more vested interest in maintaining the accuracy of any data they may be responsible for, with the obvious benefit to the overal accuracy of the information it holds.

A.2. <u>On-Going Analysis of Orders - Basic Proportion</u>

In the current O.P. system, when an order is processed its details are <u>recorded</u> on files and any subsequent analysis of orders must be made by extracting the appropriate data from these files and performing calculations on it. This is then a passive system which can only readily supply information about individual orders but not groups of orders or particular time periods.

The writer proposes that the new O.P. system should be more active, analysing orders as they are received to provide quickly available, up-to-date information about the state of outstanding orders and about past order patterns. It should be possible to extract directly from file the ordered quantities which have been requested for delivery in each future period, and this information should be available in a number of groupings, for example the following:-

Individual Part Number
Metal Type/Product Group
Industry Group
Customer (for large customers)
Representatives' area (Home trade)
Factors (Export trade)
Home/Export trade.

Other groupings may be necessary to fulfil the requirement of the production, marketing and customer service functions. To provide this information each incoming order would be processed to establish the time period(5) in which delivery has been requested and to add the delivery quantity(ies) into running totals for each coming time period for each group. In this way the current order situation is always readily available either to produce regular status printouts of committment to dispatch or to rapidly service 'special requests' for information. Each order (or modification to an order) only needs processing once on initial input and not once for each separate special analysis as in the present system. This order analysis could either be carried out on-line (as the order is entered through a V.D.U.) or during a daily batch run for orders received that day.

Simple print programs or the ICL "FIND" package could then be used to print out required order patterns direct from the file data, and forecasts/sales statistics could easily generated from that data.

Orders once satisfied should be removed from the outstanding order pattern and entered on a historical record of orders. This can then be used as an accurate basis for analysis of past Sales.

A.3. Potential Management Information from the System

Below is listed some of the possible information which could readily be generated by the system. It can be clearly seen that such information is of fundamental importance in enabling management to make well informed decisions. If the order pattern file is not constantly updated as suggested but instead only separate - unanalysed - order details are held (as at present) then the production of the management information would be slow and would involve duplication of analyses on the same data (With the consequent waste of computer processing time). It is also imperative that the data shall be complete, accurate and up-to-date for it to gain acceptance from the users and hence realise its potential usefulness.

+ Total quantity of orders already placed for each product/group/industry for each of the next weeks/months/accounting periods.
+ Historical order pattern for these groups.
+ Forecasts of eventual orders expected based on the above information.
+ Pareto analyses of various classes of products indicating the relative magnitude of sales in each class.
+ Automatic provision of a 'build-up-book' for use by production control, with automatic forecasting of required production.

It would be of particular value if much of the above information (especially historical order patterns) was plotted as graphs. This would enable users to identify more easily patterns and trends in demand.

A.4. Points to Consider in Designing System

In ensuring the completeness, accuracy and usefulness of the information the following points should be considered. They are mainly based on observed deficiencies in the existing O.P. system - the list is not purported to be exhaustive and it is in the interest of all potential users to suggest additional points to ensure a good final solution.

(i) All orders should be processed, including schedules

(ii) All adjustments to orders must be processed

(including cancellations, changed dates & quantities - Schedule ammendments are significant and <u>must</u> be included)

(iii) The system should involve the minimum of delay between receiving an order and entering it into the computer system.
This ensures firstly that the information is up to date (a backlog of unprocessed orders will distort the order pattern) and secondly that the present Ex-Stock System is not needed (Removing a source of possible ambiguity and error in the recorded data which inevitably results from a split system of data collection).

(iv) Details of NEW PRODUCTS should be entered on the file <u>before</u> orders are taken for those items (This avoids the computer's rejection of the order and subsequent delay in satisfying customer requirements - this is a significant source of agravation in the present system).

(v) If a different product is dispatched in place of that originally ordered (e.g. new-process rivets which are replacing part of the range). Then it should be ensured that the order file is ammended accordingly (at present the invoice is often ammended manually and the computer is never informed that the substitution has been made).

(vi) There should be periodic checks of overdue orders to ensure that they do not remain unactioned or to check that if they have been dispatched the dispatch acknowledgement has in fact been processed.

(vii) Facility should be made for including in overdue order totals part orders which have not been dispatched. (The customer may have agreed to accept only part of his original order, with part to be dispatched when available).

(viii) When a customer places a new order there should be a check that he does not already have an outstanding order, or remaining part of a scheduled order, for that product. (This will ensure that old or duplicate orders do not remain on file as at present).

(ix) Orders placed with no specified delivery date for all or part of the quantities should be periodically checked and if necessary the customer reminded of this outstanding quantity and asked if he will still require the goods (customers often do not bother to cancel the remaining balance of an order if they no longer require it).

(x) The normally expected range of order size for each product could be held on file. The quantities of each new order would be checked against this standard and if it exceeded the maximum expected could be flagged for attention as it may represent a very significant order (in which case sales and/or production may wish to know quickly) or may represent a large error in the details input.

(xi) Inter-company transfers should be distinguished from genuine customer or agent orders.

(xii) The present method of Folio numbers should be modified to ensure that duplication of orders can not occur if there are changes of customer details. (In the present system many orders remain on file under old folio numbers and will never be dispatched).

(xiii) Export orders should be distinguished from Home Sales since they must be produced/dispatched further in advance of required delivery date to allow for transit time. (The Production office currently enter export orders in their 'build-up-book' one month prior to delivery date).

(xiv) The clerical part of the system should be scrutinised to minimise the possibility of users 'using' the system to produce what they require without keeping it fully informed of the actual situation. (The present system allows dummy orders to be raised internally to facilitate invoice production - also the Ex-Stock system is missused in this way - especially for scheduled orders from motor manufacturers - a three month schedule is known by the sales office - but the computer is not informed of this until after each dispatch from the schedule. - The prior information exists in the Company but is not recorded on the computer files).

(xv) Classification of the industry group into which each order falls should be more rigorous than at present, (about 20% of orders are recorded as 'unclassified' at present - producing very distorted inter-group comparisons).

APPENDIX B

AIDS TO FORECASTING FOR RIVET PRODUCTION CONTROL

B.1 Discussion of the Present System

B.2 Recommended Improvements

- in principle
- computer system solution
- nomogram solution.

APPENDIX B.

Aids to Forecasting for Rivet Production Control

B.1 Discussion of the Present System

A manual system is currently used by the production controllers to predict the quantity of rivets that must be manufactured to satisfy customers' orders.

Ordered quantities are entered into a 'BUILD-UP BOOK' under the month in which dispatch is required. This is normally the requested delivery month for home orders and one month earlier for export orders (to allow for time in transit). For each rivet body type running totals of the outstanding orders for each subsequent month are kept.

Each monthly page is headed by a 'maximum build figure' which indicates the largest quantity of each rivet type which can be produced in that month. When the running total reaches this figure subsequent orders may be transferred to a later month (and the customer duly notified) or, for important orders, the 'build' figure raised and another product's figure lowered to release the necessary manufacturing capacity.

The build-up books are corrected for all changes or cancellations of order details, these and other book transactions being completed within 1-3 days of notification from the customer.

Also recorded in the build-up book are the totals of orders not satisfied in the correct month and carried forward as 'overdue' into the next month.

The books are normally closed on the 20th of each month but if the build figure is reached and is not to to be increased, then that month's sheet, for that product, is closed - although it may be re-opened later in the month if production capacity becomes available.

Thus from the build-up book can be established the quantity of outstanding orders for the next 3 months.

For each product the total quantity of orders received during each week (irrespective of the requested delivery date) is recorded on an order sheet. ('short' weeks orders are combined with the following week's to give a two week total). From these figures is calculated the average weekly incoming order rate over the last 10 weeks (i.e. the sum of the last 10 totals divided by 10).

The Present System - Forecasts

Each month the next 3 months production commitment is forecast and broken down to the required weekly average production rate. The forecast is made as follows:-

FORECAST = TOTAL ORDERS ALREADY OUTSTANDING FOR NEXT 3 MONTHS
+ TOTAL OF OVERDUE ORDERS
+ 9 x (AVERAGE INCOMING ORDER RATE).

Outstanding and overdue orders are taken from the build-up book and the average incoming rate is the 10 week rolling average already described.

The addition of nine weeks incoming orders was arrived at by - estimating that for the first month two more weeks orders were yet to be received and for the second and third month three and four weeks orders respectively.

The forecast is then divided by 13 to give the required weekly average over the next 3 months.

The Present System - Shortcomings

Although the present system works reasonably well there are some shortcomings which have to be overcome by the skill of the production controllers.

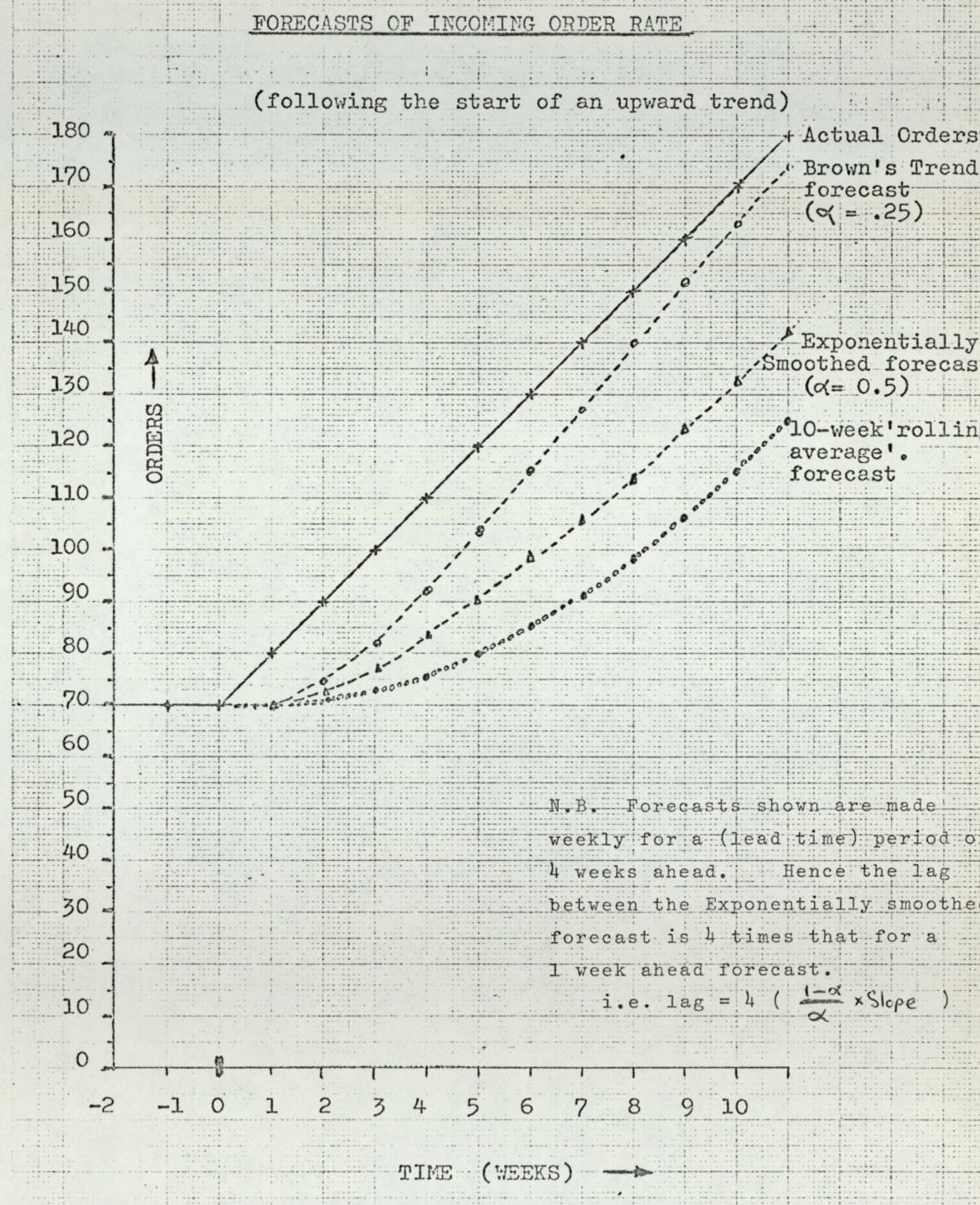
<u>The Ten Week Average</u>

Using the ten week rolling average to forecast future incoming order rates is reasonably accurate while demand for the product remains stable. If however there is a steady increase in orders the rolling average is very slow to respond (see fig.B1) and unless this error is spotted by the production controllers, production scheduled from the forecast may be well below actual requirements. Similarly if demand drops overproduction will result.

<u>Multiple Delivery Schedules</u>

When an order is received which schedules several deliveries over a number of months, the <u>total</u> quantity ordered appears in the week's incoming order figure. This will give a falsely high indication of the increase in forward weekly production committment (e.g. if an order schedules six, monthly deliveries of 4,000 rivets per month the rate at which weekly deliveries have increased is approximately 1,000/month wheras the increase of 'incoming order rate' is 24,000). The error introduced by this anomaly does however tend to nullify itself if there is a steady incoming flow of new schedules each week. If total demand was remaining approximately constant and the incoming schedules were spread evenly over the year then the incoming order rate would provide a reasonable indication of delivery rate. At Tuckers there are usually one or two periods during each year when a larger than average number of schedules are

FIG. B1


FORECASTS OF INCOMING ORDER RATE
(following the start of an upward trend)
Actual Orders
Brown's Trend forecast (α = .25)
Exponentially Smoothed forecas (α= 0.5)
10-week'rollin average'. forecast
ORDERS
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-2 -1 0 1 2 3 4 5 6 7 8 9 10
TIME (WEEKS)
N.B. Forecasts shown are made weekly for a (lead time) period o 4 weeks ahead. Hence the lag between the Exponentially smoothe forecast is 4 times that for a 1 week ahead forecast.
i.e. lag = 4 ((1-α)/α × Slope)

renewed. At such time the incoming order rate will give a falsely high indicator of delivery rate and this has to be allowed for by the production control staff. Without other analysis of order sizes it is not possible to identify if there was a real change in the level of demand during this time. More meaningful incoming order rates could be calculated from the true rise in weekly order level generated by spreading schedules over their appropriate time periods. Even so renewal of expiring schedules would affect the computed incoming order rate, unless (as in the case of major export schedules) the renewal comes at least 3 months before the previous schedule expires.

Forward Ordered Proportions

As indicated previously the figure arrived at as weekly incoming order rate is added to existing orders in the proportions of 2, 3 and 4 weeks for the next 3 months. This implicitly assumes that approximately 50%, 25% and 0% of orders are placed one, two and three months ahead of required dispatch. Experience with figures from the computer YEARSORDERS file indicates that these proportions may in practice be significantly different from the real average proportions.

Despite the above the present system does function reasonably well, the skill of the production controllers making up for some of its deficiencies. It is however evident that there are a number of improvements that could be made.

B.2 Recommended Improvements

Measuring the Incoming Order Rate

In the longer term a more detailed analysis of incoming orders is required. It would be necessary to accumulate all incoming orders broken down into weekly delivery requirements (i.e. like a build-up-book with weekly instead of monthly periods). From this it would be possible to compute the actual increase in forward committment for each week of the next 3 months, dispensing with the present assumption that this equalled the incoming order rate.

Using presently available figures this calculation could only be done monthly, which would probably not give a sufficiently rapid indication of changing order rate. The clerical work involved in weekly generation and analys of the figures would be considerable and should be a feature of the new order processing system currently under investigation. It should be possible for the new system to generate and update the build up books, as accurately as does the present manual system, whilst also generating useful management information for forecasting, production and sales planning. More detailed O.P. recommendations are included in appendix A.

Forward Ordered Proportions

In order to establish more accurately the average proportion of orders placed one, two and three months in advance of required dispatch it is necessary to collect, from the build up books, data on the proportions occuring in the past. This information is not presently available since past records do not indicate the dates on which each new order was placed, and hence how far in advance. The writer has suggested a simple change in the clerical system which will start to generate the information required, and the production controllers are now carrying it out. At the monthly close of the books (20th day) a line is drawn under the last running total for each of the subsequent three months, with the month written beside it. In (say) six months it will then be possible to look back at the books and for each past month there will be four figures of interest - the actual total orders at the close of that month and the cumulative totals that had existed 1, 2 and 3 months in advance. When sufficient data becomes available a regression analysis could be carried out to establish the forward order proportions.

Where the book was closed prior to the 20th due to production constraints then this will also be indicated, to show that the figures have been artificially limited.

The Ten Week Average

It is likely to be many months before an improved computer order processing system can provide the weekly analyses required to give the true incoming rate of weekly production committment and so it will be necessary for some time to continue using existing figures of incoming order rate.

As shown in fig. B.1 the ten week average used at present is very slow to respond to changes in the pattern of demand. Also shown on fig. 1 are the responses of an exponentially smoothed forecast and of Brown's (1959) linear trend method. These show a considerably improved response to the upward trend. Calculations for the smoothed average could be readily made by hand using a calculator or nomogram but the trend method would require some extra clerical effort.

Two possible solutions are proposed. The first is the provision of a simple computer system to accept weekly incoming order rate figures and forecast by each of the methods mentioned. The specification of such a system has been placed with the Systems Development Manager, but due to shortage of programmers it is unlikly that this system will be initiated in the near future.

The second solution is the use of a nomogram to reduce clerical effort in computing trend forecasts. A nomogram is a graphical technique which, using the principles of co-ordinate geometry, enables the drawing of straight lines between scales on a chart to yield the same answer as an arithmetic calculation. Its advantages are that it can be fairly easily understood by 'non-mathematical' clerical staff and can be quickly carried out without the aid of a calculating machine.

A suitable nomogram technique for producing linear trend forecasts by Brown's (1959) double smoothing method is developed by Lewis (1970 c) and Lahri (1971).

Lewis (1972) developes a generalised γ-period ahead forecast from Brown's method and describes a simple nomogram to calculate it, as shown below:-

where α = a smoothing constant in the range 0-1.0

and d_t = the incoming order quantity last period

the exponentially smoothed average

$$= u_t^* = \alpha d_t + (1-\alpha) u_{t-1}$$

the double exponentially smoothed average

$$= \bar{u}_t = \alpha u_t + (1-\alpha) \bar{u}_{t-1}$$

---

* Subscripts refer to the time period of the value.

e.g. d_{t-1} = orders last but one period

d_t = orders in last period (just finished)

$d_{t+\gamma}$ = orders in γ periods time.

then Lewis's generalised forecast for γ periods ahead

$$= f_{t+\gamma} = 2\,u_t - \bar{u}_{t-1} + \alpha(\gamma-1)\,(u_t - \bar{u}_{t-1})$$

Construction of the scales of the nomogram is shown in fig. B.2 which was used to compute both the exponentially smoothed and trend forecasts in fig. B.1. Measurements shown across the bottom of fig. B.2 show the relative distances between the scales, the value D being arbitrary depending on the width of the chart to be drawn.

The forecasts are generated as follows:-

(1) Find u_t by drawing a straight line between d_t (the last incoming order total) and u_{t-1} (the last single smoothed average).

(2) Draw a straight line between this value of u_t and $\bar{u}_{t-1}$ (the last double smoothed average) and extend this to the appropriate $f_{t+\gamma}$ scale. This gives the forecast $f_{t+\gamma}$ ahead and also the new value of $\bar{u}_t$.

It can be seen that the values of $\bar{u}_t$ and u_t calculated each period must be recorded each time and will be used as $\bar{u}_{t-1}$ and u_{t-1} respectively in the following period's forecast.

The writer suggest that (at least for products with large sales volumes) the results of the weekly forecasts, by 10 week average, exponentially smoothed average (u_t) and trend method, together with the actually occuring incoming order totals, should be plotted graphically (one for each product), similar to fig. B.1. From this it could easily be seen which method was providing the most accurate forecast, and also by presenting orders graphically give the production controllers more subjective 'feel' for the order pattern.

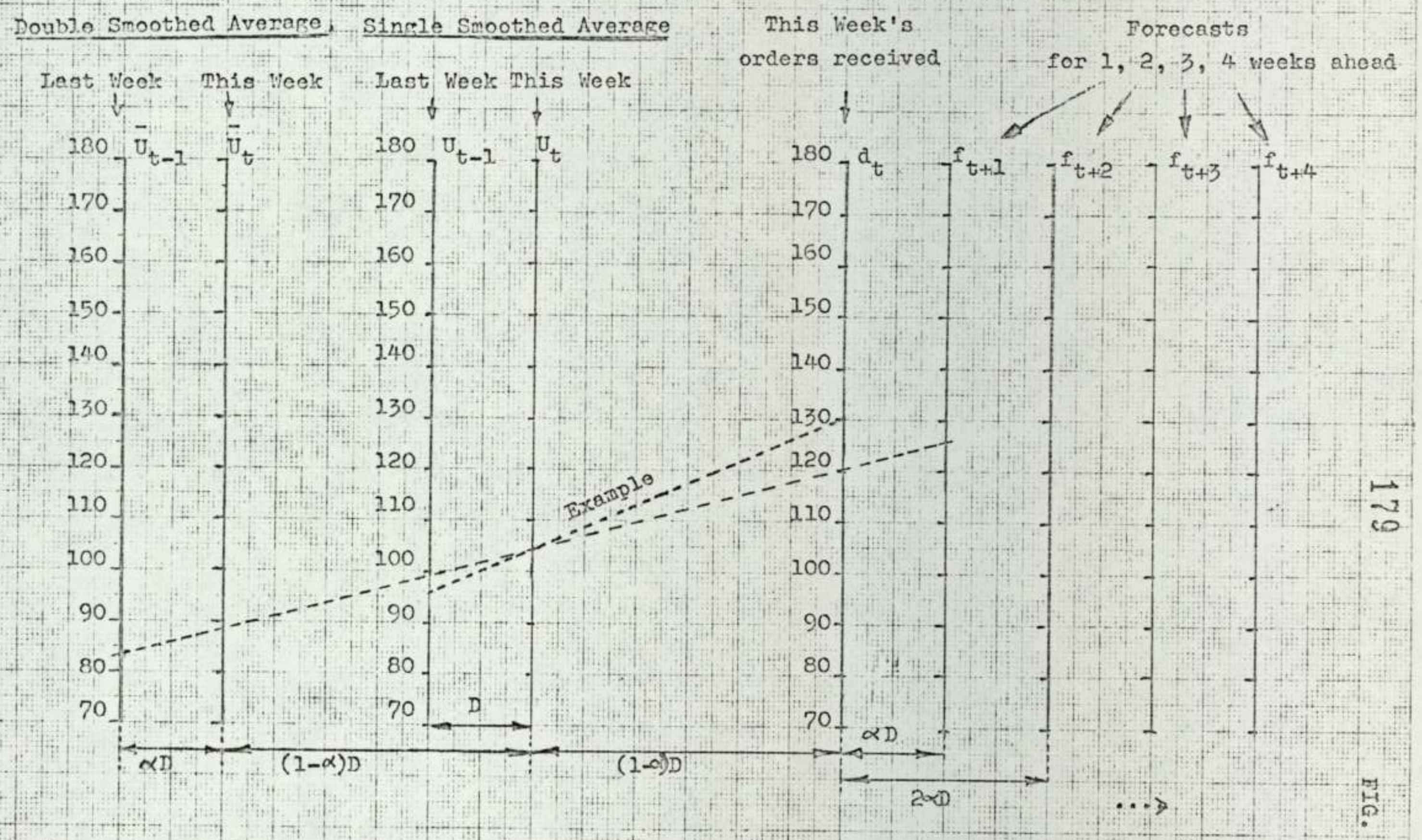


FIG. B2. NOMOGRAM FOR CALCULATING TREND FORECASTS ($\alpha = 0.25$)

APPENDIX C

COMPUTER PROGRAM TO ESTABLISH OPTIMUM FORECASTING PARAMETERS AND COMPARE FORECASTING METHODS

Programming Language Fortran IV

Program Code Number SF5Ø

C.1 Listing of Program Statements

C.2 List of Main Variables in the Program.

C. 1. Listing of FORTRAN Statements.

```
       LIST(LP)
       PROGRAM(SF50)
C     ======================================================================
       COMPRESS INTEGER AND LOGICAL
       OUTPUT 2=LP7
       INPUT 3=CR4
       INPUT 4 =MT4/FORMATTED(FCDATA)/372
       CREATE 5=MT5/FORMATTED(FINF)/318
       TRACE 2
       END
       MASTER SF50
       REAL ITLE
       INTEGER PR1,PR2,PR3,PR4,FAC(28),FAKTR
       DIMENSION HIS(20 ),SD(20),SUM(20 ),STORE(4,20 ),FAKTR(7),FMT(2),
      1OPFAC(4),FCAST(20 ),FERR(20 ),OPALF(4),SDER(4),ABFER(4),
      2 ERMEN(4),SMAD(4),SAMEN(4),SDFUN(4),FUMEN(4),AMAD(4),SMERR(4),
      3OLAV(4),TREND(4),FOCST(4),TNRIG(4),OTRIG(4),ALF(20),SUMSQ(4),F(20)
      4,ARR(5,20 ),LINE(106),KF(12),WW(2),AHD(20),FMAT(2),ERMAG(4,20 )
      5,AHDATA(18,3) ;ERVAL(4),ITLE(3)
       DATA ZED/8HZZZZZZZZ/,BLANK/1H /,STAR/1H*/,ONE/1H1/,TWO/1H2/,THREE/
      11H3/,FOUR/1H4/,LINE/106*8H        /,EP/8HENDPARTS/,NIN/8H99999999/
      2, ITLE(1)/6H HOME /,ITLE(2)/6HEXPORT/ ,ITLE(3)/6H TOTAL/
      3 ,UNIT/4HX100/
       CALL DATE (WHEN)
C
C  READ CONTROL CARD
C
       READ(3,1)INPT,AMIN,AMAX,DEL,ALFSM,II,JJ,KK,MIN,PR1,PR2,PR3,PR4,,LY
      13,LEADC,JIGL,AMN,DELT,FMIN,FDEL,(FAKTR(I),I=1,7)
     1 FORMAT(I1,4F2.2,9I1,I3,I1,1X,4F2.2,4X,7I5 )
C
C   FAKTR(1) =ICT  =1 FOR CARD I/P , =3 FOR TAPE
C
C   FAKTR(2) =IA   -% ERR ROUTINE FINDS IA'TH HIGHEST ERROR
C
C
C  PRINT CONTROL DATA
       WRITE(2,2) WHEN ,
      1             AMIN,AMAX,DEL,ALFSM,II,JJ,KK,M1N,PR1,PR2,PR3,AMN,DELT,
      2FMIN,FDEL,(FAKTR(I),I=1,7 )
     2 FORMAT(1H1, 10(/) ,4X,A8,10X,23HSF50 CONTROL PARAMETERS /   22X,
      123(1H=)/// ,          40H  MINALF  MAXALF  STEP   SMTHC   METHODS ,
      2 4X,56HMINIMISE   PRINT 1 , 2 , 3      AMN   DELT   MINAH   DELT //
      3 4X,4(F5.2 ,2X) , 3(1X,I1 ) , 9X , I1, 12X , 3(1X,I1,2X)      ,
      4 4(2X,F5.2 )  ,4(/) , 2X 21HINPUT FACTORS  1 TO 7 // 4X,7(I5,2X) )
C
       ICT =FAKTR(1)
C
       IF(ICT-3)0,1000,0
       IF(ICT-1)0,1000,0
       STOP NOT13
  1000 IF(ICT-1) 10,0,10
C   CARD INPUT DATA
C
       L,LL=FAKTR(5)
       READ(3,3)K,(FMAT(I),I=1,2)
       NN=K+1
```

```
      C
      C   KA = K+L  ALWAYS  ***
      C
            READ(3,3)KA,(FMT(I),I=1,2)
          3 FORMAT(I3,2A8)
      C
      C READING CARD INPUT DATA  -K DATA ITEMS , K+L 'AHEAD' ITEMS
      C NB:NUMBER OF 'AHEAD' ITEMS MUST = NUMBER OF 'ACTUALS' + FACTOR(5)
      C
         12 READ(3,13)AL,BL,CL,DL,EL,FL,GL,HL,HI,UNIT,LEAD
         13  FORMAT(A8,A6,6A8,A3,A4,2I3)
            CALL COMPR(AL,ZED,IJ)
            GO TO(150,0),IJ
            KB1 =K+1
            READ(3,FMAT)(HIS(I),I=2,KB1)
            READ(3,FMT)(AHD(I),I=1,(K+L))
            HIS(1) =HIS(2)
            GO TO 1015
      C
      C
      C TAPE INPUT DATA FROM FCDATA
      C
         10 READ(4,11)AL,MGP,IHX,((HIS(I+1),(AHDATA(I,J),J=1,3) ),I=1,18)
         11 FORMAT(A8,I2,I1,3X,72F8.0)
      C
      C  READ DESCRIPTION CARD FOR EACH PART NO. -MAY BE BLANK -NO CROSS CHECK
      C
            READ(3,1199)CL,DL,EL,FL,GL,HL,HI ,PR3
       1199 FORMAT(20X,6A8,A3 ,2X,I1 )
            CALL COMPR(AL,EP,IEP)
            GO TO(600, 0) ,IEP
            CALL COMPR(AL,NIN,IZD)
            GO TO(550,0),IZD
            K=15
            HIS(1)=HIS(2)
            CALL COPY(6,BL,1,ITLE(IHX),1)
            IF(HIS(2))1015,0,1015
            FACN,FACO = 0.6
            GO TO 1916
       1015 FACN,FACO = AHD(1)/HIS(2)
      C
      C  LOOP 3 TIMES FOR TAPE DATA  -ONCE FOR CARD DATA
      C
       1916                                                  DO 500 NRUN=1,ICT
            GO TO(1016, 0 , 0), ICT
            L,LL = NRUN
            DO 1115 I=1,18
            NN =K+1
            AHD(I)=AHDATA(I,NRUN)
       1115 CONTINUE
       1016 CONTINUE
            CALL FMOVE(HIS,SUM,K+1)
            DO 1017 I=1,NN
            ARR(5,I) =SUM(I)
       1017 CONTINUE
      C
      C
      C  OPTIMUM PREDICTION PARAMETER SEARCH
      C  ======= ========== ========= ======
```

```
C
C    INITIAL VALUES FROM FIRST 5 PERIODS
C
   20 TOTAL,SQTOT=0
      DO 21 I=1,5
          TOTAL =TOTAL+HIS(I)
           SQTOT=SQTOT +HIS(I)**2
   21 CONTINUE
      SDEV =SQRT((5*SQTOT -TOTAL**2 )/20)
C
C  FORECAST METHODS  TO BE TESTED DEFINED BY II,JJ,KK (FROM CONTROL CARD
C
   25 DO 85 METH=II,JJ,KK
          LASRN=1
          NALFS=IFIX((1+(AMAX -AMIN)/DEL) * METH )
          IF(NALFS-1)29,29,0
      IF(METH -2) 30,30 ,0
      NALFS =2
      GO TO 30
   29     LASRN=2
          ALF(1)=AMIN
          SSD =100000
C
C  LOOPING FOR EACH VALUE OF SMOOTHING CONSTANT ALF(M)
C
   30     DO 70 M=1,NALFS
      GO TO(31,32)LASRN
   31           ALF(M) =AMIN +DEL*(M-1)
   32         SMERO,FERSQ,FERSU,SUMAD,SQMAD,TRIGO,FEPAB,FUNSU,FUNSQ,TREN
     1O,TRENE =0.0
C  WORKING THROUGH THE NN ITEMS OF HISTORY IN ARRAY SUM( )
C
                         TRIGN =0
                      OMAD , AMADN =0.8 * SDEV
C
C  SETTING INITIAL AVERAGE
C
      OLDAV=TOTAL/5
   35           DO 60 I=1,NN-1+L
                      GO TO(44,45,47,46)METH
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C   FORECAST METHOD 1  SIMPLE SMOOTHED AVERAGE  (AVNEW)
C                      ====== ======== =======
   44 IF(I-L+1)0,0,441
      AVNEW =OLDAV
      GO TO  442
  441 AVNEW =ALF(M)*HIS(I-L+1)  +(1.-ALF(M))*OLDAV
  442 FCAST(I)=AVNEW
      F1 =FCAST(I)
      IF(METH-3)50,45,50
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                      GO TO 50
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C METHOD 2 -FORWARD LOADING
C
   45  FACT= ((ALF(M)-AMIN)/DEL)*FDEL + FMIN
      AVNEW ,FCAST(I) =AHD(I)/FACT
```

```
      F2 =FCAST(I)
      IF(METH-3)50,47,50
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                      GO TO 50
C     ------------------------------------------------------------------
C
C .   F'CAST METHOD  4  - TRIGG'S ADAPTIVE
C
   46 IF(I-L+1)0,0,461
      AVNEW =OLDAV
      GO TO 462
  461 AVNEW =(ABS(TRIGN))* HIS(I-L+1)+(1.-ABS(TRIGN))*OLDAV
  462 FCAST(I)=AVNEW
C------------------ ----- -------- ---- ---- --- ---- --- --- -- --- -
                      GO TO 50
C
C METHOD 3  1+2 COMBINED
C
   47 IF(I-1)0,0,471
      WT=0.5
      GO TO 474
  471 S12=STORE(1,I-1) +STORE(2,I-1)
      IF(S12)0,0,473
      WT=0.5
      GO TO 474
  473 WT=STORE(1,I-1)/S12
  474 FCAST(I)= WT*ARR(2,I) +(1-WT)*ARR(1,I)
      AVNEW = FCAST(I)
C     --------------------------- ---------------------------------------
C  FORECAST METHODS  1,2,3 RETURN FORECAST OF NEXT LEAD TIME DMD:FCAST()
C             WHICH IS COMPARED WITH THE ACTUAL:SUM( ) TO GIVE ERROR,FER
C
   50          IF(FCAST(I)) 0,51,51
               FCAST(I) =1
C
C LAST L FORECASTS HAVE NO LEAD TIMES FOR ACCURACY CHECK
C
   51          IF(I-NN+1)0,0,590
               FER =SUM(I+1) -FCAST(I)
                   SMERN =ALFSM * FER + (1-ALFSM)*SMERO
                   OMAD =AMADN
                   AMADN=ALFSM * ABS(FER) + (1-ALFSM) *OMAD
                   STORE(METH,I)  =AMADN
                   IF(AMADN) 52,0,52
                   TRIGN =0.1
                   GO TO 53
   52              TRIGN = SMERN/AMADN
   53              FERR(I)=FER
                     FERSQ =FERSQ +FER**2
                     FERSU =FERSU +FER
                     SUMAD =SUMAD +AMADN
                     SQMAD =SQMAD +AMADN**2
                     FUNSU =FUNSU +FER/AMADN
                     FUNSQ =FUNSQ +(FER/AMADN)**2
                     SMERO =SMERN
                     TRIGO =TRIGN
                     OTRIG (METH) =TRIGO
                     OLDAV =AVNEW
                     GO TO(59,58)LASRN
```

```
   58 EPMAG(METH,I) =FER/SSD
   59              FERAB        =FERAB + ABS(FER)
                   TREND =TRENF
C
C STORING ARRAY ARR() FOR GRAPH SCALING
C
  590  ARR(METH,I)=FCAST(I)
   60          CONTINUE
               ONO = FLOAT(NN-1)
               SD(M)= SQRT((ONO *FERSQ -FERSU**2)/(ONO*(ONO -1,)))
C
C    FOR LASRN =1 -CARRY OUT OPT ALFA SEARCH
C    FOR LASRN =2 -CARRY OUT FINAL RUN AT OPTIMUM ALFA+STORE FINAL VALUE
C    ALSO SET CRITERION FOR CHOOSING OPTIMUM ALFA
C
               GO TO(62,80)LASRN
   62          GO TO(63,64,65,66)MIN
   63          F(M)=FERSQ
               GO TO 70
   64          F(M)=FERAB
               GO TO 70
   65          F(M)=SD(M)
               GO TO 70
C  66 IS RESERVED FOR INSERTION OF ANY FURTHUR DESIRED CRITERION
   66          CONTINUE
   70      CONTINUE
C
C  SEARCH FOR OPTIMUM ALFA (IE. LEAST VALUE OF F(M) )
C
           NMIN = 1
           SMALST =F(1)
   72      DO 75 I=1,NALFS -1
               IF(F(I+1) - SMALST)74,75,75
   74          SMALST =F(I+1)
               NMIN = I+1
   75      CONTINUE
           AF,OPALF(METH)=ALF(NMIN)
           GO TO(0,76,77,78),METH
           OPFAC(1) =AF
           GO TO 79
   76        OPFAC(2) = (NMIN-1)*FDEL +FMIN
           GO TO 79
   77      OPFAC(3) =0
   78      OPFAC(4) =0
C
C  INSTRUCTING FINAL RUN AT OPTIMUM ALFA
C
   79      LASRN = 2
           NALFS =1
           ALF(1)=OPALF(METH)
           SSD =SD(NMIN)
C
           GO TO  30
   80      SDER (METH)=SD(M)
           ERMEN(METH)=FERSU/ONO
          MEENER = ERMEN(METH)
           SMADLY =((ONO*SQMAD -SUMAD**2)/(ONO*(ONO-1,))) **2
           SMAD (METH)=SMADLY**0.25
           SAMEN(METH)=SUMAD/ONO
```

```
          SDFUN(METH)=SQRT((ONO *FUNSQ -FUNSU**2)/(ONO*(ONO-1,)))
          FUMEN(METH)=FUNSU/ONO
          AMAD (METH)= OMAD
          SMERR(METH)= SMERO
          OLAV (METH)= OLDAV
          TREND(METH)=TRENO
          ABFER(METH)=FERAB
          FOCST(METH)=FCAST(NN-1+L)
          TNRIG(METH)=TRIGO
          SUMSQ(METH)=FERSQ
   85 CONTINUE
C
C  % ROUTINE FINDS THE IA'TH HIGHEST ABSOLUTE ERROR
C
      IA =FAKTR(2)
      K= 15
      IB=K
      PERC= (FLOAT(K-IA+1) / FLOAT(K) ) *100
      DO 855M=1,JJ
      UPR =8000000
      IPAS=1
      DO 84 I=1,IA
          DO 83 J=1,IB
              IF(UPR- ABS(ERMAG(M,J)))83,83, 0
              GO TO( 0 , 81 ),IPAS
              TOP =ABS(ERMAG(M,J))
              IPAS=2
              GO TO 83
   81         IF(TOP -ABS(ERMAG(M,J))) 0, 83, 83
   82         TOP = ABS(ERMAG(M,J))
   83     CONTINUE
          UPR =TOP
          IPAS=1
   84 CONTINUE
       ERVAL(M) =TOP *SDER(M)
  855 CONTINUE
      WRITE(2,86) WHEN,L,AL,BL,CL,DL,EL,FL,GL,HL,HI,UNIT,AL,BL
   86 FORMAT(1H1/4X,A8,18X,35HS050   OPTIMUM  FORECAST SIMULATION   ,9X,
     110HFORECASTS   ,I2,14H PERIODS AHEAD   //4X,A8,A6,9X,6A8,A3,5X,7H(
     2UNITS  ,A4,2H ),7X,A8,A6 / 4X,14(1H-),85X,14(1H-))
C
C  PRINTING SIMULATION RESULTS
C
      IF(PR2)95,95,0
      WRITE(2,88)
   88 FORMAT(1H0         4X,109HACTUAL    :   FORECAST METHOD  1     :   FO
     1RECAST METHOD  2    :   FORECAST METHOD  3    :  FORECAST METHOD
     24   / 15X ,4(1H.,25X) / 5X, 111HDEMAND      .      F'CAST     ERR/SD
     3  .      F'CAST      ERR/SD    .     F'CAST      ERR/SD     .    F'CAST
     4      ERR/SD  / 15X, 4(1H.,25X) )
       DO 91 I=1,K
       WRITE(2,90)I,SUM(I+1), ((ARR(M,I),ERMAG(M,I)),M=1,4)
   90  FORMAT(1X,I3,3X,F9.0    ,4(4X ,F9.0,3X ,F6.3,3X, 1H. ))
   91 CONTINUE
      DO 93 I=(K+1),(K+L)
      WRITE(2,92)I, (ARR(M,I) , M=1,4 )
   92 FORMAT(1X,I3,11X,1H. , 4(4X,F9.0 ,12X,1H, ) )
   93 CONTINUE
      WRITE(2,94) (OLAV(I),I=1,4),(TNRIG(J),J=1,4),(AMAD(I),I=1,4),
```

```
      1(SMFRR(I),I=1,4) ,PERC,(ERVAL(I), I=1,4)
   94 FORMAT(1H ,1X,118(1H.)                 /2X,11HLAST VALUES // 2X,
     112HSMOOTHED AV. ,5X ,4(   F9.0,17X)  / 5X,5HTRIGG ,11X , 4(  F6.3,
     220X ) /  6X,3HMAD ,10X , 4(  F9.0, 17X  )   / 2X,12HSMOOTHED ERR ,
     35X,4(F9.0 ,17X) /F4.0 , 9H % ERR +-,6X , 4(F9.0 ,17X))
   95 IF(PR1)132,132, 0
C-----------------------------------------------------------------------
C
C  PRINTOUT OF FORECAST METHOD COMPARISON
C
      WRITE(2,97)
   97 FORMAT(1H /22H SIMULATION COMPARISON   / 7X,110(1H.)/7X,1H.,42X,
     135HOPTIMUM FACTOR CHOSEN TO GIVE LEAST     )
      GO TO(100,102,104,106)MIN
  100 WRITE(2,101)
  101  FORMAT(1H+,85X,32HSUM OF SQUARED F'CAST ERRORS  ,     )
      GO TO 110
  102 WRITE(2,103)
  103 FORMAT(1H+,85X, 33HSUM OF ABSOLUTE F'CAST ERRORS,        )
      GO TO 110
  104 WRITE(2,105)
  105 FORMAT(1H+,85X,33HSTD DEVN OF F'CAST ERRORS       .    )
      GO TO 110
  106 CONTINUE
C 106 RESERVED FOR ADDITIONAL CRITERION
  110 WRITE(2,111)
  111 FORMAT(7X,110(1H.)/7X,1H.,18X,18HFORECASTING ERRORS,16X,1H:,9X,1H:
     1,7X, 5HM A D,13X,21H.   (FCAST ERR/MAD) ,/2X,6HFCAST,,52X,11H. OPT
     2IMUM .,25X,1H.,19X,1H./2X,16HMETH .    SUM OF,7X,13HSUM OF       .,
     322X,57 H. FACTOR  .    MEAN        STD DEVN   ,   MEAN   STD DEV  ./
     37X,31H.    SQD ERS      ABSOLUTE ERS .,   23H  MEAN      STD DEVN
     3,,9X,27H.     MAD          MAD         .,19X,1H./
     47X,1H.,29X,1H.,22X,1H.,9X,1H.,25X,1H.,19X,1H.)
      DO 116 I=II,JJ,KK
          WRITE(2,115)I,SUMSQ(I),ABFER(I),ERMEN(I),SDER(I),OPFAC(I),SAME
     1N(I),SMAD(I),FUMEN(I),SDFUN(I)
  115 FORMAT(3X,I1,5H    . ,1PE12.6, 3X,1PE11.5,3H  .,0PF8.0,2X,F8.0,  6H
     1     . ,F5.2,5H   . ,F9.0,3X,F9.0,5H    . ,F6.1,2X,F6.1,5H     ./
     1 7X,1H.
     1 ,29X,1H.,22X,1H.,9X,1H.,25X,1H.,19X,1H.)
  116 CONTINUE
      WRITE(2,117)
  117 FORMAT(7X,110(1H.))
  132 IF(PR3)347,347,0
  307 WRITE(2,308)WHEN ,CL,DL,EL,FL,GL,HL,HI ,UNIT, AL,BL,L
C
C PRINT FORMAT 3 - LEAD TIME VALUES VS. F'CASTS   - GRAPH
C
C-----------------------------------------------------------------------
C
C  CHOSING SCALE
  133 GTEST =0
      DO 302 I=1,5
          DO 302 J=1,NN
              IF(GTEST -ARR(I,J))301,302,302
  301         GTEST =ARR(I,J)
  302 CONTINUE
      N=0
      DO 303 I=1,9
```

```
          IF(GTEST -10.0)304,304,0
          N=N+1
          GTEST=GTEST /10.0
  303 CONTINUE
  304 MAXVAL =IFIX(GTEST)
      IF(MAXVAL -2)305,0,0
      IF(MAXVAL -5)306,0,0
      MAXCALE =3
      GO TO 309
  305 MAXCALE =1
      GO TO 309
  306 MAXCALE =2
C
C     PRINTING TITLE AND ORDINATE AXIS
C
 308  FORMAT(1H1 // 3X,A8,8X,6A8,A3, 5X,5HUNITS,2X,A4,8X,A8,A6 //20X,
     115HFORECASTS MADE , I3 ,14H PERIODS AHEAD )
 309  WRITE(2,310)N
  310 FORMAT(1H0,92X,20HORDINATE VALUES X10E,I3,5H      )
C
C  WRITING  ORDINATE  VALUES
C
      GO TO(312, 0 ,314),MAXCALE
      WRITE(2,311)
  311 FORMAT(17X,102H0         0.5        1.0        1.5        2,0        2.
     15        3.0        3.5        4.0        4.5        5,0)
      GO TO 316
  312 WRITE(2,313)
  313 FORMAT(17X,102H0         0.2        0,4        0.6        0.8        1.
     10        1.2        1.4        1.6        1.8        2,0)
      GO TO 316
  314 WRITE(2,315)
  315 FORMAT(17X,102H0          1          2          3          4          5
     1          6          7          8          9          10  )
  316 WRITE(2,317)
  317 FORMAT(17X,10(10H+    +    ),1H+/17X,101(1H+))
C
C  PLOTTING DATA
C
      GO TO(320,321,322),MAXCALE
  320 FACTOR =50
      GO TO 323
  321 FACTOR =20
      GO TO 323
  322 FACTOR =10
  323 DO 346 J=2,(NN+L)
            DO 345 I=II,JJ,KK
         IF (I-II) 0,0,3250
               IF(J-NN)0,0,325
               LIN5=NINT(ARR(5,J)*FACTOR/10**N) +1
  325          IF(J-1)345,345,0
 3250          LINU =NINT(ARR(I,J-1)*FACTOR/10**N) +1
         IF (I-II) 0,0,329
  326          IF(J-NN)0,0,3261
               CALL COPY(1,LINE(LIN5),1,STAR,1)
 3261          M=J-1
               WRITE(2,327)M,(LINE(LI),LI =1,101)
  327          FORMAT(16X,1HI/12X,I3,1X,1HI,101(A1))
               CALL COPY(1,LINE(LIN5),1,BLANK,1)
```

```
   328          IF(J-1)346,346,0
   329          GO TO(331,332,333,334)I
   331         CALL COPY(1,LINE(LINO),1,ONE,1)
                GO TO 335
   332         CALL COPY(1,LINE(LINO),1,TWO,1)
                GO TO 335
   333         CALL COPY(1,LINE(LINO),1,THREE,1)
                GO TO 335
   334         CALL COPY(1,LINE(LINO),1,FOUR,1)
   335          WRITE(2,340)(LINE(LI),LI=1,101)
   340          FORMAT(1H+,16X,101(A1))
               CALL COPY(1,LINE(LINO),1,BLANK,1)
   345     CONTINUE
   346 CONTINUE
  347  GO TO (12,0,0) ,ICT
C
C WRITING TO FINE FILE  .FIRST CONVERT DATA TO INTEGER
C
       FAC(2 )=NINT (1000 * OPFAC(2))
       FAC(3 )=NINT (100  * OPFAC(1))
       FAC(4 )=NINT (100  * ALFSM    )
       FAC(5 )=NINT (  OLAV(1) )
       FAC(6 )=NINT (100  * TNRIG(1))
       FAC(7 )=NINT (100  * TNRIG(2))
       FAC(8 )=NINT (100  * TNRIG(3))
       FAC(9)=0
       FAC(10)=NINT ( AMAD(1) )
       FAC(11)=NINT ( AMAD(2) )
       FAC(12)=NINT ( AMAD(3) )
       FAC(13)=NINT ( SMERR(1))
       FAC(14)=NINT ( SMERR(2))
       FAC(15)=NINT ( SMERR(3))
       FAC(16)=NINT ( ARR  (  1, 16 ) )
       FAC(17)=NINT ( ARR  (  1, 17 ) )
       FAC(18)=NINT ( ARR  (  1, 18 ) )
       FAC(19)=NINT ( ARR  (  2, 16 ) )
       FAC(20)=NINT ( ARR  (  2, 17 ) )
       FAC(21)=NINT ( ARR  (  2, 18 ) )
       FAC(22)=NINT ( ARR  (  3, 16 ) )
       FAC(23)=NINT ( ARR  (  3, 17 ) )
       FAC(24)=NINT ( ARR  (  3, 18 ) )
       FAC(25)=NINT ( ERVAL( 1) )
       FAC(26)=NINT ( ERVAL( 2) )
       FAC(27)=NINT ( ERVAL( 3) )
       FAC(28)=NINT ( ERVAL( 4) )
C
       WRITE(5,410)AI,MGP,IHX,MRUN, (FAC(I),I=2,28)
  410 FORMAT(A8,I2,I1,3H000,I2,1X,I3,2I2,I8,5I5,   20I8 )
  500 CONTINUE
       GO TO 1000
C
C WRITES 3 DUMMY RECORDS AS S046 READS 3 RECORDS AT A TIME
C
C
C WRITING 3 ENDPARTS RECORDS
C
  600 DO 610 I=1,3
          WRITE(5,510)EP  ,I
  610 CONTINUE
```

```
      GO TO 10
  550 DO 511 I=1,3
          WRITE(5,510)ZED ,I
  510     FORMAT(A8,6X,I2,  186X)
  511 CONTINUE
C-----------------------------------------------------------------------
  150 WRITE(2,151)WHEN
  151 FORMAT(1H0,20X,A8,5X,18HSO50 RUN COMPLETED/20X,8(1H=),5X,18(1H=))
      STOP
      END
```

C.2 List of Main Variables

ABFER	Sum of Absolute forecasting errors.
AHD	Monthly forward order loading.
AHDATA	" " " " (tape input data)
ALF	Exponental Smoothing Constant.
ALFSM	Smoothing Constant for Smoothed error, MAD etc.
AMAD	Mean Absolute Deviation (MAD) - stored value.
AMADN	Newly Calculated MAD - each loop.
AMAX	Maximum smoothing constant tried in simulation.
AMIN	Minimum " " " " "
AMN	Alternative forecast constant minimum (not used in listing).
ARR	Array holding lead time demands and f'casts (for graph plott).
AVNEW	New smoothed average.
DEL	Increment between smoothing constants tried.
DELT	Alternative increment - used with AMN.
EP	Name given to End-of-part number file marker.
ERMAG	Stored value of forecast errors.
ERMEN	Mean forecast error for each method.
ERVAL	Highest error magnitude on % of forecasts.
F	Store for run values of factor to be MINimised.
FAC	Array storing integer values prior to writing tape file.
FACT	Forward load Factor used in Method 2.
FACTOR	Scaling factor in graph plotting routine.
FAKTR	Series of factors input on control card.
FCAST	Forecast for each period.
FDEL	Increment of forward load constants tried.
FERAB	Absolute forecast errors - working store.
FER	Forecast error value - working store.
FERR	" " " - permanent store.
FERSQ	Sum of squared f'cast errors.
FERSU	Sum of f'cast errors values.
FMT	Format of forward order load cards.
FMAT	" " actual " " "
FMIN	Minimum forward load constant tried.
FOCST	Store for each method's best forecast.
FUMEM	Mean value of (forecast error/MAD).
FUNSQ	Sum of squares of (" " / ").
FUMSU	Sum of values of (" " / ").
F1,F2	Forecasts by methods 1 and 2 for use in method 3.
GTEST	Greatest value to be plotted on graph.
HIS	Record of single periods demand.

list of variables - (cont).....

ICT	Indicates no. of simulations on each data set.
IHX	Home/export indicator - 1 = Home, 2 = Export, 3 = both.
II/JJ/KK	Indicates forecast methods to be tried.
INPT	Not used.
IPAS	Logic indicator in PERC % highest error routine.
ITIE	Literal title store - Home/export/total.
JIGL	Not used.
JJ	See II.
K	Number of periods data input by card.
KK	See II.
L,LL	Lead time - working value.
LASRN	Indicator to show last run for each method.
LEAD	Lead time input by card for each separate item.
LEADC	" " " on control Card for that run.
LINE	Array holding a line of characters for graph plot .
LINO	Position on LINE where forecast value appears.
LIN5	Position on LINE where actual values appears.
LY3	Not used.
MAXCALE	Indicates 1 of 3 graph scales to be plotted.
MAXVAL	Integer value of largest value plotted.
METH	Indicates forecast method in loop.
MGP	Material group code.
MIN	Instructs parameter to be minimised in search.
NALFS	Number of smoothing constants tried.
NN	Value = K + 1.
OLDAV	(old) Smoothed average calculated at last pass.
OLAV	(old) Smoothed average - permanent store.
OPALF	Optimum ALF for method 1.
OPFAC	Optimum factor for each other method.
OTRIG	(old) Trigg's signal calculated at last pass.
PERC	Percentage of forecasts falling within % ERVAL error.
PR1-PR4	Indicators to instruct/suppress print routines 1-4.
SAMEN	Mean value of MAD.
SD	Std. deviation of errors for each method.
SDER	" " " " - permanent store.
SDEV	
SDFUN	Std. deviation of (f'cast error/MAD).

list of variables - (cont)....

SMAD	Std. deviation of MAD.
SMERN	New value of smoothed error.
SMERO	Old value " " "
SMERR	Smoothed error - permanent store.
SQMAD	Sum of squares of MAD.
SQTOT	Sum of values of MAD.
SSD	Std. deviation of errors - working store.
STORE	Record of MAD's for use in method 3 weighting.
SUM	Lead time values.
SUMAD	Sum of MAD's - working store.
SUMSQ	Sum of squares of MAD - working store.
TNRIG	Trigg's factor - permanent store.
TOP	Largest forecast error magnitude.
TOTAL	Sum of first 5 periods orders.
TREND	Trend value } for use if
TRENE	" " } trend forecast methods are
TRENO	" " } tested.
TRIGN	New value of Trigg's factor - working store.
TRIGO	Old " " " " " "
VPR	Highest value so far in error size search.
WHEN	Alphanumeric date - called from computer.
WT	Weighting factor in method 3.
ZED	Name given to end of file marker.

APPENDIX D

SUM OF SQUARED ERRORS BY THREE METHODS OF FORECASTING.

Forecasts of: monthly demand for main rivet groups.

Forecast methods used:

1 = Exponential Smoothing

2 = Forward Order Loading

3 = Combination of 1 and 2.

Results obtained from: Initialising run of the automated sales forecast system - generated by the program which optimises forecast method.

Tables Show: Sum of squared forecasting errors (SSE) for forecasts made 1, 2, and 3 periods ahead. Results marked with asterisk(s) are significantly smaller than one (*) or both (**) of the other results at the 5% level using the F test. S.S.E.'s were derived from comparison of 18 periods actual-forecast values. From F test tables of 17 x 17 degrees of freedom at the 5% level the minimum

$$\frac{\sigma_L^2}{\sigma_S^2} \text{ ratio}$$

which is significant $\simeq$ 2.27

where σ_L^2 = larger S.S.E.

σ_S = smaller S.S.E.

D1. Forecasts Made 1 Period Ahead

(sum of squared errors to 3s.f. x 10^6)

Rivet Product Group		Forecasting Methods 1	2 (1.75)	3
Sealed	Home	1.73	1.17	0.99
	Export	6.19	3.82	2.03 *
Alloy	Home	10.8	8.85	9.41
	Export	33.7	5.46 *	12.8 *
Monel	Home	0.872	0.807	0.547
	Export	3.99	1.06 *	1.23 *
Steel	Home	1.07	1.30	0.730
	Export	0.817	0.129 **	0.527

NOTE: Results marked by * or ** indicate that the S.S.E. is significantly smaller (at the 5% level) than one, or both, of the other methods.

D2 **Forecasts Made 2 Periods Ahead**

(Sum squared errors to 3s.f. x 10^{6})

Rivet Product Group		Forecasting Methods 1	2	3
Sealed	Home	2.14	1.75	1.32
	Export	8.69	5.64	4.26
Alloy	Home	12.09	33.5	29.9
	Export	49.9	10.45 *	* 7.35
Monel	Home	1.25 *	7.09	1.62*
	Export	5.55	1.37 *	1.57*
Steel	Home	1.36	3.31	2.62
	Export	0.776	0.571	0.385*

NOTE: Results marked by * or ** indicate that the S.S.E. is significantly smaller (at the 5% level) than one, or both, of the other methods.

D3. **Forecasts Made 3 Periods Ahead**

(Sum of squared errors to 3s.f. x 10^6)

Rivet Product Group		Forecasting Methods 1	2	3
Sealed	Home	2.77	5.34	3.69
	Export	11.67	13.6	7.96
Alloy	Home	15.11	42.4	36.0
	Export	70.74	190.0	122.0
Monel	Home	1.56 **	10.26	11.2
	Export	7.88	8.67	3.37**
Steel	Home	1.37 **	13.88	13.58
	Export	0.915 **	2.52	2.68

NOTE: Results marked by * or ** indicate that the S.S.E. is significantly smaller (at the 5% level) than one, or both, of the other methods.

APPENDIX E.

THE NORMAL DISTRIBUTION.

Standard Deviate (k)	Probability of stockout occurring (%)
1.0	15.9
1.10	13.6
1.20	11.5
1.30	10.0
1.40	8.1
1.50	6.7
1.60	5.5
1.70	4.5
1.80	3.6
1.90	2.9
2.00	2.3
2.25	1.2
2.50	0.6
2.75	0.3
3.00	0.1

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