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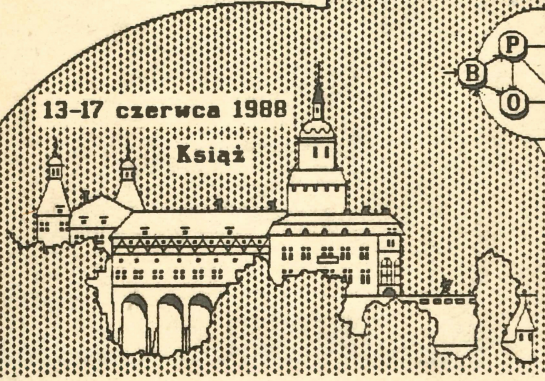


1. Krajowa Konferencja Badań Operacyjnych i Systemowych

Tom 1

BOS'88

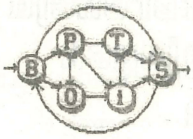
POLSKIE TOWARZYSTWO BADAŃ OPERACYJNYCH I SYSTEMOWYCH

INSTYTUT BADAŃ SYSTEMOWYCH POLSKIEJ AKADEMII NAUK

POLSKIE TOWARZYSTWO BADAŃ OPERACYJNYCH I SYSTEMOWYCH

Tom 1

OPTYMALIZACJA METODY I ZASTOSOWANIA



I KRAJOWA KONFERENCJA BADAŃ OPERACYJNYCH i SYSTEMOWYCH

Książ, 13 - 17 czerwca 1988

BOS'88

INSTYTUT BADAŃ SYSTEMOWYCH POLSKIEJ AKADEMII NAUK

1989
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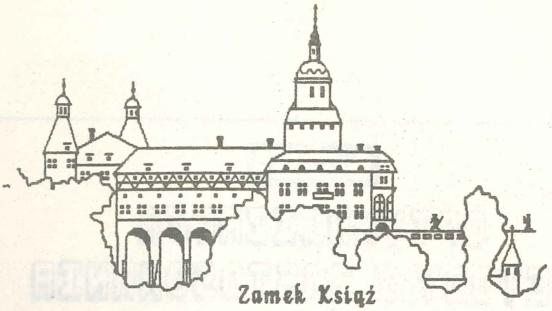

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1. Referaty gości zagranicznych

1.1

I Krajowa Konferencja
Badań Operacyjnych i Systemowych
Książ, 13 - 17 czerwca 1988r.

OPERATIONAL RESEARCH IN THE BRITISH INLAND LETTER SERVICE

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Starting with a general description of the British Postal System and its main variables the paper goes on to outline the work already done, principal results and current work programme of research. The second half of the paper discusses how results of Operational Research and Statistics Research are used to assist management in control of costs and quality of service.

INTRODUCTION

The main system operated by the Postal Business is a network of operational units spread over the country to facilitate distribution of inland letters and packets from posting to delivery to customer' premises. The same operational units also deal with letter mail from and to other countries but for clarity these mails will not be considered any further in the paper. The inland system operates at two service levels; - first class where the objective is to deliver 90% one day after posting and 2nd class where the objective is to deliver 96% of such mail three days after posting.

For the purpose of day to day operational control and management the network is divided between some 64 District Head Postmasters' geographically distinct areas, and these are then grouped into Territories. The direct management line of reporting and control is District Head Postmaster to Territorial General Manager to Managing Director of the Letters Business. Letter Business Headquarters functional Departments (Planning, Marketing, Personnel, Finance, Engineering R and D and Buildings) have responsibility for development of overall policy and the executive tasks which need to be performed for the whole system. The other businesses of the Post Office are Royal Mail Parcels, Counters, and the Giro Bank and are managed through their own management structures. All businesses are subject to the control and direction of the Main Board of the Post Office of which the four managing directors are members. Operational Research and Statistics units exist in the other businesses but their current work programme and past results are not considered in the paper.

LETTER MAIL SYSTEM (INLAND)

One of the first difficulties confronting an operational researcher who has to analyse a network system as complex as the mail system, within which all operational units mutually interact both with respect to service and operational costs, is to find ways of representing the network in a simplified form, both as an aid to remembering the system complexity and also so that the essential nature of the system is clearly brought out. Fig. 1 is one such representation of the mail system from which it can be seen how letter mail flows (left to right in the diagram) through the various kinds of operational units starting with being posted in a letterbox or at a "post office" and finishing with delivery by a postman to a recipient's home or business premises.

The approximate number of operational units in each stage of this network is shown at the bottom of Fig. 1 and for day to day operational control and management they are allocated to the geographically exclusive District Head Postmasters' areas. The diagram brings out quite clearly that each posted item can indeed reach its destination and that only in its journey between outward processing and inward processing is there an alternative route, ie it can either travel via a general forwarding/distribution office or directly to inward processing. Further, although the diagram brings out that the matrix of flows is really between some 100,000 posting boxes and the 23 million locations to which mail is delivered, the heart of the system is the matrix of flows between outward processing offices and inward processing offices with some of the flows going via general forwarding or distribution offices. Up to the outward stage mail flows are progressively combined to give outward processing a reasonable volume for efficiency and from inward processing onwards they are progressively disagregated so that delivery to individual customers may be accomplished. The above general properties of the network allow a more useful overall representation of the system and this is shown in Fig 2.

This representation brings out that the input to the system is essentially controlled by the posters of mail, and that the system is a sequence of individual processes which involves queuing. It is also clear that the operational schedule of each process affects the schedule of all processes which are downstream and to an extent those upstream and hence operational scheduling is one of the main technical problems of the Letters Business.

Overall system "optimization" was never seriously considered as a practical possibility[2] and the system research that has and is being done is aimed at developing practical methods of evaluating performance of individual processes, operational units and to find better ways of operating the system. Before the last aspect can be progressed it is necessary to understand and devise practical methods of dealing with problems inherent in:

(a) sorting of mail
(b) circulation of mail
(c) delivery of mail
(d) scheduling of operations.

The approach adopted since 1966 was to develop (and or use existing knowledge) models to represent processes, eg sorting and delivery. Computing power was then somewhat limited, expensive and could not be made available to operational units. In the late 70's computers were sufficiently cheap and powerful to tackle circulation and scheduling. Since then the arrival of micro computers - powerful and very cheap - has opened up most areas of Postal activity and planning tasks to computer modelling approach.

The "models" that have been developed (of both kinds) will now be described in approximately the chronological sequence of their development.

MODELS - DEVELOPED AND UNDER DEVELOPMENT

1. Sorting

Collected mail has diverse physical characteristics (eg, with postage stamps, meter mail, chunky packets, 1st or 2nd Class, machine sortable or not, postcoded or not, etc) and therefore has to be segregated into different processing streams, "faced" (ie, addressed and stamps on all items facing the same way), stamps cancelled and then sorted and despatched to appropriate destinations. Some 70% of mail posted in a typical District area is for other Districts. Sorting can either be carried out manually using an array of apertures or containers (box fitting or drop bag fitting) or mechanically in which case the mail has to be coded in order to translate the postcode into machine readable form. In general all the despatched mail is sorted again at the inward processing stage and some of it will also have been in addition sorted at the general forwarding/distribution processing stage.

Overall, letter mail receives approximately three sorting handlings so efficient sorting plans are of significant importance. Fortunately for postal OR the fundamental work which is relevant to the question of how to construct an efficient sorting plan at an individual office is that due to the work of Huffman[11], Shannon, et al on information theory. Briefly,

given that mail is to be sorted to N destinations and that the probability that an item of mail bears address Nj is Pj and that the sorting frame used has n pigeon holes (selections) then from information theory one obtains that the average number of sortations per item cannot be less than 1 where

$$I = -\sum_{j=1}^{N} P_j \log_n P_j \quad \text{- - - - - - - - (1)}$$

and it was Huffman who, given the array of Pj's, devised an algorithm for constructing a sorting plan which will result in minimum average sorting handlings but which nevertheless will be higher or at best equal to 1. The above results are very helpful when workload models of individual sorting offices are constructed since in principle the sorting workload can be represented as

$$W_S = \sum_{i=1}^{K} T_i \times h_i \times t_i \quad \text{- - - - - - (2)}$$

where WS = sorting workload in work units
Ti = number of items in the ith stream
hi = number of sorting handlings in the ith stream
ti = time for one handling in the ith stream.

Estimation of probabilities of individual mail flows is somewhat costly and the probabilities are not very stable. In practice rank order distributions are approximately the same for all operational units and these can be used for preliminary evaluation of sorting problems in order to establish whether accurate data is required.[3]

2. Delivery (Town Areas) Model:

The Post Office delivers mail to nearly 23m addresses of which 80% are in town areas. All town areas receive 2 deliveries of mail Monday to Friday and a single delivery on Saturday. These deliveries are effected from 1300 town delivery offices by 44,000 postmen. In attempting to estimate or model letter delivery workload we have used as our unit the delivery office since this is an individually managed work place. The problem of modelling the workload is not a trivial one since there are a large number of relevant factors such as:

Number of delivery points
Proportion of addresses receiving mail
Traffic (ie no of letters) per call
Balance of traffic between 1st and 2nd delivery
Business/residential traffic split
Day of week traffic pattern
Type of housing
Size and shape of delivery office area
Position of office in the area.

Further, workload estimation procedures (or models) need to be cheap, simple, logical and fair. But fairness requires accuracy, and accuracy requires some amount of detail, so it may not be possible to meet all these requirements. A balance is therefore necessary, depending on the particular application.

POSTAL LETTER MAIL SYSTEM — LOCATION OF RESOURCES AND PRINCIPLES OF MAIL CIRCULATION

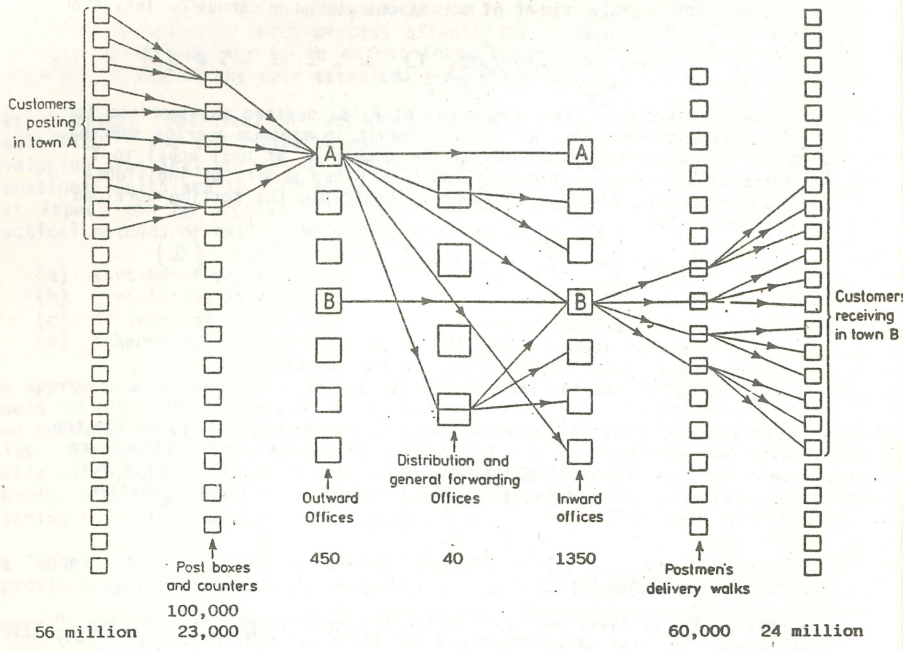


FIG. 1

POSTAL SYSTEM — SIMPLIFIED DIAGRAM OF THE MAIN SEQUENCE OF PROCESSING LETTERS

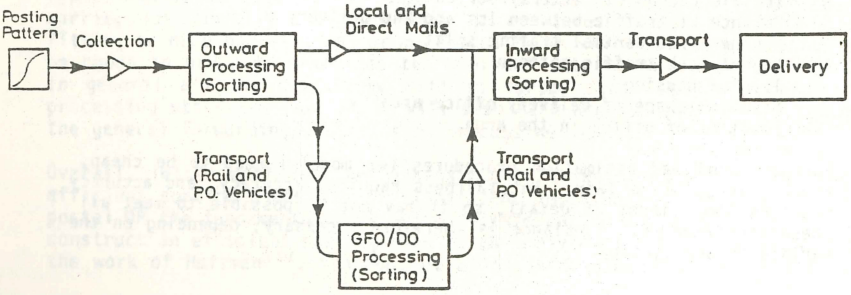


FIG. 2

The delivery staff hours required to service a town delivery area can be divided into the following four components:-

(a) Time spent on mail preparation: this is the process of sorting the letters to be delivered on a postman's walk into the order in which he will have to deliver them.

(b) Calling Time: ie, the time occupied in covering the distance between the street and recipients' letter boxes and in actually effecting delivery.

(c) Time spent walking the streets between the first and last address on the delivery round.

(d) Time spent travelling from the delivery office to the first address on the delivery round and in returning to the office from the last address on the round.

To model delivery it is necessary to develop procedures for assessing each of these components. I shall not describe the details here, but papers (4)(5) on the subject have been published. In algebraic form the town delivery model is as below.

COMPONENTS	MODEL STRUCTURE	ALGEBRAIC FORM
PREPARATION TIME	TRAFFIC / PREPARATION RATE	$\frac{T_1}{P_1} + \frac{T_2}{P_2}$
CALLING TIME	NO. OF DELIVERY POINTS × PROPORTION CALLED AT × AVERAGE TIME PER CALL	$D \times \left(\frac{m}{1+m}\right) \times t$
STREET TIME	STREET DISTANCE WALKED / WALKING SPEED	$\frac{2L}{W} \times f\left(\frac{m}{1+m}\right)$
TRAVELLING TIME	NO. OF JOURNEYS × AVERAGE JOURNEY LENGTH ÷ TRAVELLING SPEED	$\frac{2N \times \left(R - \frac{2XL}{N}\right)}{V}$
TOTAL TIME	NO. OF WALKS × AVERAGE TIME SPAN	$N \times S$

T_1, T_2 – Traffic to firms and residential customers respectively.
P_1, P_2 are preparation rates.
m – Average number of items per residential delivery point.
f – Function from calibration.
L – Length of streets in town delivery office.
N – Number of walks.
R – Random radius.
K – Constant.

The above model has been extensively calibrated (1977) and used for performance evaluation of delivery offices (300 or so implemented at one stage). Typical data collection costs 1 man week of work per office. The model has been used for regional performance comparisons and to monitor delivery at national level. It has been used for evaluation of delivery policy options and other applications.

1. the length of the working duty;
2. the number of days in the week on which deliveries are made;
3. the number of deliveries per day;
4. the partitioning of traffic between the present two daily deliveries.
5. specific planning problems, eg given a large town, into how many delivery office areas should it be divided?

6. devising productivity payment schemes, either by using the model as a direct workload measure or by producing from it the elasticities of workload to letter traffic and the number of addresses;
7. calculating marginal costs for marketing pruposes.

3. Circulation: By circulation, we mean the transfer of letters from the 450 or so "outward" offices despatching mails to the 1350 "inward" offices This includes the timing and number of despatches made between pairs of offices, the route and transport used and whether correspondence travels direct or via one or more intermediate offices. Direct despatches between a pair of offices are made if the daily average number of letters between the offices exceeds a "despatch standard". Where a direct mail is not warranted, correspondence will be routed via a Distribution Office (serving one or more counties) where the mail will be amalgamated, sorted and forwarded to the inward offices. For distant counties, a Travelling Post Office - ie a sorting carriage on a train - may be used, so that sorting and conveyance can be done concurrently. To reduce the workload at intermediate offices, letters for those inward offices for which the average flow exceeds a "selection" standard (but is below the "despatch" standard) are bundled and labelled so that the whole bundle can be sorted as a single item at the intermediate office.

The model (First approach) (1979). Clearly, this system is highly interactive. For instance, the timing of despatches from each outward office affects the times at which work is available at all inward offices. We have not attempted optimisation (except in the relatively trivial sense of choosing numerical values of eg despatch standards in a specified circulation system), but rather we built a model which allowed different circulation arrangements to be compared. Again, because of the size of the problem, and the cost of obtaining detailed data, the model was deterministic, though it was intended that stochastic versions of individual sections would be developed so that the consequences of ignoring variability could be assessed. The model took a matrix of traffic flows, details of the available transport and a set of despatching rules and either estimated the service resulting from specified levels of staff and other resources, or estimated resources needed to provide a specified level of service. It was implemented as a suite of programs on an IBM 3033 computer. Individual programs represented transport to outward offices; between outward, intermediate and inward offices; and from inward offices to their dependent delivery offices. Local transport was represented as transfers at standard times and speeds. For longer distance transport the model used actual or proposed timetables. Other programs represented sorting and allied work in each kind of office, as a series of queues with specified working rates and priorities for different kinds of mail. Parallel queues represented mechanised and manual letter sorting and packet sorting. Office output patterns determine the volume of mail available for each despatch, and processing at inward offices determines the service given to each. Summing over despatches gave service estimates for routes, offices, regions etc as required.

Result: The approach was ambitious since it aimed at estimating the effect of circulation and resource changes in terms of costs and service effects. The model proved relatively cheap to represent on the computer but not really sufficiently calibratable for management to have confidence in its estimates. Much was learned and parts of model (eg the traffic matrix) proved very useful for other application. The general conclusion was that costs, service and traffic could not be modelled simultaneously for a large postal network at the level of detail such that the model is convincing to managers as a creditable analogue of the real system.

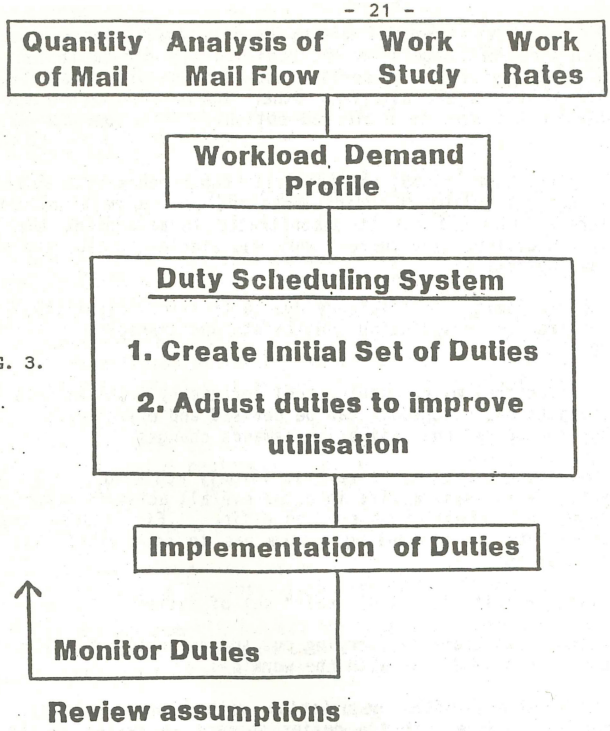
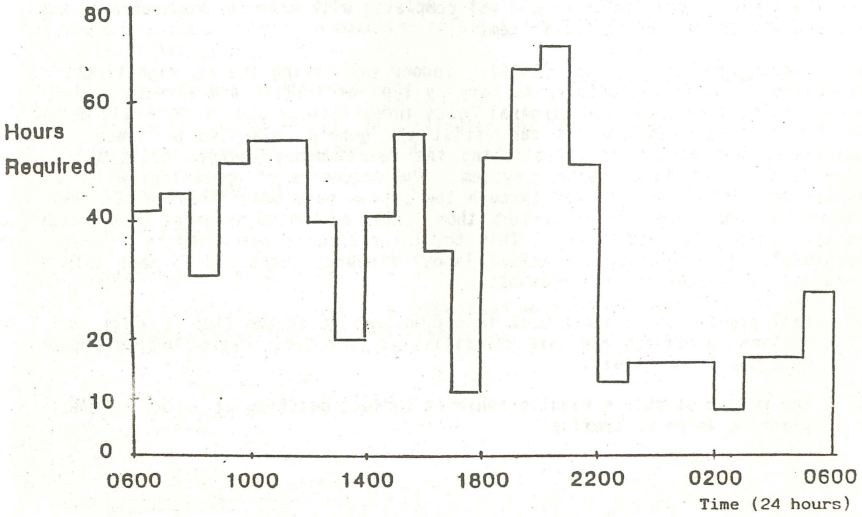


FIG. 3.

FIG. 4. **A TYPICAL WORKLOAD PROFILE**



Current Modelling (1986): With powerful micros readily available we are building and calibrating network models on the basis of one office to all others and first exploring the effect on service when traffic is switched or despatch and selection standards are altered. Other models will tackle the resultant cost effects of the service preferred options. This approach is proving successful.

4. Scheduling: The early work [6](1969) was primarily concerned with examining the question of efficient scheduling of coding desks and sorting machines. It is now only of historical interest but it demonstrated to management the crucial importance of scheduling. The current work was started in 1986 and has the following two broad objectives.

1. To establish the limits to efficiency due to traffic variability, peakiness of traffic, despatching constraints and transport reliability.

2. To develop a practical microcomputer tool for use by local offices so that an efficient basic schedule can be devised and effectively altered when the operational situation demands changes.

This work is still in progress but objective 2 is largely achieved[7]. Fig. 3 shows where the Duty Scheduling system fits into the overall activity concerned with revision of operational schedules of sorting offices. Fig. 4 shows the kind of workload variability the scheduling system has to cope with. The system assists the planner to:

1. Quickly devise an initial, "first draft" set of duties.

2. Improve on the first draft by carrying out and reporting on a detailed comparison of duties with the workload.

Implementation of the duties, after negotiation with trades union representatives, then takes place with the duties subject to review in the light of changing circumstances.

The DSS has been written in compiled BASIC on an Apricot XI small business computer and consists of a suite of 25 programs together with 'help' screens. A training programme for planning staff has been designed and run by OR staff and the training program is around 75% complete, with a large proportion of the trained offices now using the system.

5. Indoor Processing Model (1985). Indoor processing has no significant economies of scale but unit costs vary by type of traffic and service. The model was used for Long Run Marginal Costs investigation and is currently being further developed so that it can assist the general planning of indoor operations and assist in establishing the relationship between costs and service and a practical control system. The sequences of operations which a letter may undergo on its way through the system have been itemised and the labour resource necessary to perform those tasks evaluated assuming that labour is used with total efficiency. This total resource is described as a "core workload". In practice, the actual labour resource necessary to meet this workload is greater for two reasons:

a) Mail traffic is variable both in its volume and in the time at which it arrives in offices and this volatility is to a large degree unpredictable on a day to day basis.

b) The nature of duty schedules inhibits perfect matching of labour to the planning level of traffic.

The modelling resolution to the problems of traffic peakiness and volatility has been to specify the timing of activities undertaken by Outward, Inward and Distribution functions based on a set of offices chosen as representative of the system as a whole, not in the statistical sense of being "average" offices, but in the sense of being located within the sorting network to encompass different operational conditions.

The model has been written in compiled basic on an Apricot XI small business computer. The calibration of the model has begun and it now has to tackle not only its own objectives but also the first scheduling objective (see page 6).

6. Service Model: In 1986 it was recognised that, following the setting up of Letter Districts and the demise of Regions, some means was required of identifying how the Q of S provided by different Districts was affected by their position in the postal network and by other 'system' variables. OR&S agreed therefore to develop a mathematical model quantifying how quality of service was affected by various important system parameters. The first use of the model was to assist in setting district and sector targets for 1987/88.

The Q of S model was developed by examining Q of S actually achieved and correlating it with certain system parameters. Data from sample surveys was available on Q of S performance but we have no information on how each sample item actually circulated through the system. Information on circulation arrangements was obtainable from the Letter Mails Circulation computer system (LMC). But this system contains no actual Q of S or traffic flow information.

However Letter Information System (LIS) does identify the collecting office and the delivery office for most items sampled. This enabled us to proceed by:

a. Extracting from LIS for all the samples of interest, ie first and second class eligible items, certain information including the Q of S achieved, the collection and delivery offices, and the method of cancellation.

b. Using a reference file to identify the inward and outward vouching offices for each sample. The grid references of each delivery and posting office were also contained in the reference file.

c. Adding routing characteristics from Outward Office to Inward Office by cross-reference to LMC information.

Some technical problems remain eg the validity of using the main despatch to represent a flow; how to remove the effect of unusual operational situations at some offices.

The main parameters in the model are:

a. Type of delivery office. In particular the proportion of mail delivered by a small delivery office (SPSO).

b. Distance travelled.

c. Route taken.

d. Number of links on route.

e. Inland air services. We have identified an effect of air services only for mail travelling more than 250km.

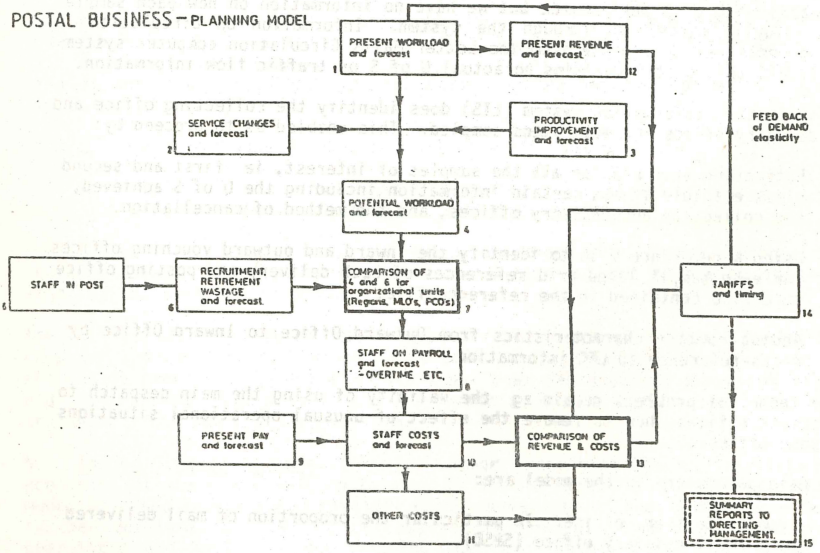
f. Travelling Post Offices. We have identified a direct effect for this at distances between 100km and 250km.

g. Cross London transfer.

h. Miscellaneous effects.

The model has been used for setting Service Targets to and from individual districts two years running, ie 87/8 and 88/9. A full technical report will be issued shortly and further refinements and development is expected. However since a different measure of service is about to be introduced the model will need redevelopment once sufficient new service data is available.

Scope for further modelling:
The six models, briefly described above, have concentrated on individual problem areas. The Operational Research and Statistics division is currently part of the Planning department and therefore the development of the Business planning model may well receive priority. Below is an outline of such a model.



It's not appropriate to discuss this model but it could be developed; if it was as sound as say the delivery model management would have an extremely powerful means of reliably analysing several of the key decision made yearly (pay, tariffs, efficiency and manpower supply) and their implications.

Other models which need to be developed cover in general the non labour costs of the business (eg accommodation, administration, etc) and it may be desirable to develop models to assist the settlement of contract payments for services provided to and from other Postal Businesses.

IMPLEMENTATION EXPERIENCE AND PROBLEMS.

1. Policy evaluation: The main contributions are in policy areas concerned with evaluation and control of: mechanisation,[8] delivery, circulation[8] and long run marginal costs[9] and therefore tariffs for particular types of traffic. No undue difficulties have emerged in this area of activity mainly because senior management are fairly well aware of the structure and validity of the models and critical assumptions can be subjected to sensitivity analysis.

2. Development of tools for direct use by staff in operational units: The main contributions are:

   1. Computer Assisted Delivery Revision (CADR),[10]. A microcomputer device which helps the planner to string together a postmen's "walk" keeping watch on method of delivery of each postcode, total workload at each stage and to overide the computer advice when the use of local knowledge is required.

   2. The Duty Scheduling System (see page 6).

Problems Encountered in Implementing A Computerised Planning Tool in the Post Office (Based on the DSS Experience But Equally Applicable to CADR)[11, 12]

As an integral part of the implementation of DSS, the OR group undertook the training of representatives from local sorting office planning teams. We identified (by job designation) who the most appropriate trainees would be in terms of understanding and using the system. However, in practice, the calibre of the trainees (and hence potential users) was highly variable. The desired combination of computer aptitude and PO operational know-how was rarely to be found in one individual. In addition the motivation levels we came across in trainees were also highly variable and this was to prove crucial in the perceived "success" or "failure" of the computer system. In addition to the "users" it proved to be important that other managers were fully informed of what the system could (and couldn't) do. In the early stages, there were instances where managerial misunderstanding led to unrealistic expectations and hence frustrations. The follow-up effort which was required in addition to initial training in the use of the system proved to be substantial in terms of the time required from the OR group. This is a very brief summary of an important issue but highlights the need to develop tools for users as they are - sophisticated OR and Statistics ideas and procedures need to be translated into every day commonsense language and procedures.

CONTRIBUTION TO MANAGEMENT CONTROLS.

The main contributions are to:

1. Budgetary control
2. Service targets
3. Performance evaluation.

Budgetary Control: Although budgets for each operational unit are set by the directorate OR and Statistics has contributed to the estimation of by how much resources need to be increased purely for traffic growth and changes to delivery points. The indoor processing and delivery model are the most relevant to this area of control. Up till now "sensitivities" used are the "national" values. It is likely that some allowance for inter office differences will need to be made and work is proceeding to establish practical means since it is not feasible to run the main models for each district each year.

Service targets: The main model is of course the service model (page 7), however, much more important is that managers in general have received the targets as fair and logical. Technical problems apart, the model is proving very useful in assisting management to concentrate on specific areas of service shortfall and influencing decisions on routing and system configuration.

3. Performance evaluation: Direct contribution in the past was mostly made by individual OR and Statistics staff acting in a sense as "auditors" on behalf of management. Currently, we are involved with management in the development of performance evaluation system to be used by finance and operational management directly. The development aims to be comprehensive and cover all important components of a line managers responsibility such as, staff and other costs, service, capital investment, projects, etc. I hope to report later on the success and other aspects of this system.

ABOUT THE OPERATIONAL RESEARCH AND STATISTICS DIVISION.

The unit operates as internal consultants in operational research, statistics and systems development. OR started in 1966, statistics several years earlier. Till 1986 the two groups operated as separate divisions and were expected to look after the needs of all services of the British Post Office (Letters, Parcels, Counters and Giro). Currently each business has a combined OR and Statistics unit. Letter Business, a relatively larger one - 21 professional staff, Parcels 6 and Counters 3. The growth of professional staff has been steady over the 20 plus years (eg The Letter Business in 1981 employed some 15 whereas in 1966 about 6, mainly statisticians). All indications point to a very healthy situation, but since the work programme is shifting towards operational and business planning and overall management control systems much depends on whether staff stay sufficiently long (7 years?). They have to gain comprehensive experience, understanding of operations, establish a reputation for competence and involvement before they can successfully contribute at the more strategic level.

The main components of the current work programme are:

1. Quality of Service Measurement Systems.
2. Integrity and accuracy of sampling systems.
3. Implementation of practical aids to management and control of operations at district level.
4. OR and Statistics contribution to specific projects by Planning Department and others. eg Review of transport mode balance.
5. Development of Models for Business Planning - evaluation of strategic issues.

The work programme is divided among the senior consultants on the basis of their experience and we attempt to keep the work programme balanced between sections so that all individuals can acquire a good appreciation of the whole of the Letters Business. The professional staff frequently work in project teams with our client departments who provide some of the staff required for detailed data collection and field inspections.

Acknowledgement: The paper reviews the contribution made by many individuals and to them I am grateful, the views expressed are my own and not necessarily those of the Post Office.

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PION III